INTERNATIONAL TRADE IN POULTRY MEATS

Dale Colyer and Walter Labys

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Dale Colyer and Walter Labys are professors in the Division of Resource Management of the West Virginia University College of Agriculture, Forestry and Consumer Sciences.

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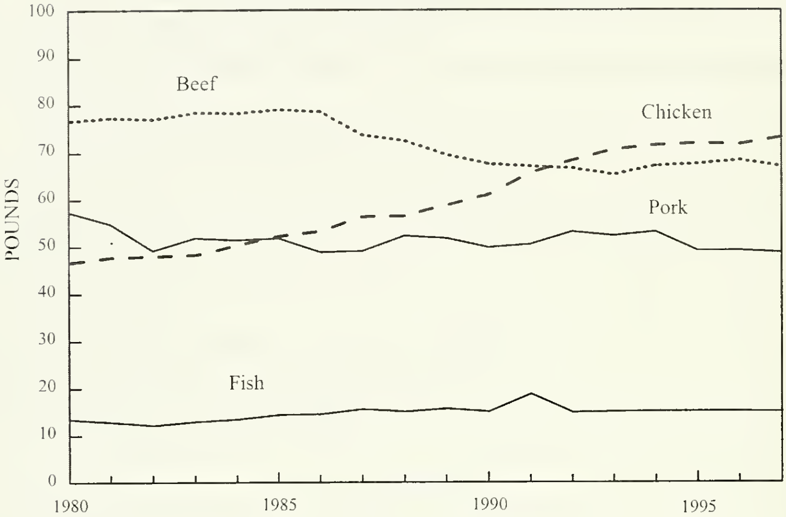
INTRODUCTION

International trade in poultry products was a relatively unimportant factor in the industry until the 1980s and 1990s when exports began to grow more rapidly and became a more significant proportion of the market for both broilers and turkeys. The United States is both the s largest producer and the largest exporter of poultry products in the world, producing around one fourth of all poultry meats and accounting for well over one third of total exports. In recent years, 15 percent or more of the U.S. output has been exported, with the majority of the exports accounted for by sales of broiler parts, especially the dark meat cuts which are relatively low in price due to the demand for white meat in the U.S. The purpose of this publication is to review and analyze the growth of international trade in poultry meats and the factors that affect that growth. The production of eggs is important in the poultry industry, but is not being covered in this analysis. Thus, references to the poultry industry in the remainder of this report refer to poultry meat.

PART I. POULTRY PRODUCTION AND TRADE

The poultry meat industry has grown rapidly in recent decades and poultry has become an important food source in many parts of the world, mainly due to its being a relatively low cost meat and an excellent source of animal protein that is perceived as contributing to a healthy diet. Thus, per capita consumption of chicken in the United States now exceeds that for beef, which previously had been the main supplier of animal protein (Figure 1). Technological change, which enables poultry meat to be produced with less grain per pound than beef or pork, accounts for much of the economic advantage, although mechanization and the vertically

Figure 1. U.S. Per Capita Consumption of Meats



integrated structure of the poultry industry also have been significant contributors to greater efficiency in the production and processing of chicken and turkey products. In addition poultry meat, especially the white cuts, is a relatively low fat product with less cholesterol than red meats, a factor that strengthens the demand for those products by an increasingly health-conscious public.

The Poultry Industry

Poultry meat products have become increasingly important sources of food in the United States and throughout the World in recent years, primarily because they provide a cheaper source of protein than other meat products. However, poultry still constitutes only about one fourth of

the world's meat production, although contributing nearly one half to U.S. meat supplies. The growth of the industry is attributable to improvements in technology and changing consumer tastes and preferences.

The U.S. Poultry Industry

The U.S. poultry industry is concentrated on the production of chicken (primarily broilers) and turkeys, although ducks, geese and other fowl also are produced. In 1998, chicken accounted for 36.1 percent of total meat consumption in the U.S. compared with 32.2 percent for beef and 24 percent for pork; per capita consumption of all chicken was 75 pounds *vs*. 68 pounds of beef and 54 pounds for pork (USDA 1999). Turkey meat production was 6.9 percent of the total, with consumption at about 18 pounds per capita. Other poultry meat (duck, goose, emu, ostrich and game birds) contributed only about 0.12 percent of the production totals for all meat. All poultry accounted for 43.1 percent of total meat production.

During the last half of this century, poultry production has been transformed from a small enterprise carried out on a large number of farms to a highly specialized and vertically integrated industry with relatively few farms producing large amounts of poultry. According to the 1997 Census of Agriculture, 5 percent of U.S. farms had chickens in 1997, whereas only 3.2 percent sold poultry or poultry products. In 1950, over 78 percent of the nation's farms had chickens while the corresponding number was over 90 percent in 1920 (Perry, Banker and Green 1999). Thus, poultry production has changed from a small, supplemental enterprise carried out by a large share of the nation's farms to one characterized by a relatively small number of large, highly specialized operations under contracts with a few large vertically integrated firms.

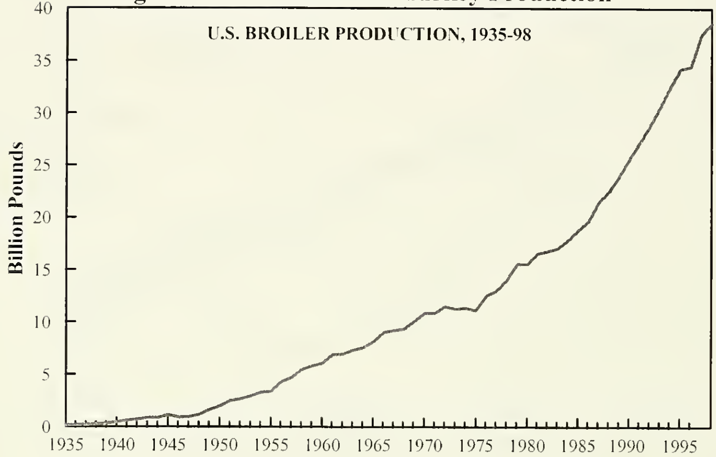
Poultry production has grown rapidly, with production of broilers rising from only 96.5

million pounds in 1934 to 38.5 billion pounds in 1998 (Figure 2). Turkey production also has increased at a rapid pace, rising from less than one billion pounds in 1960 to over 7 billion in 1998 (production data for turkeys were not reported for earlier dates). These rapid increases are due largely to technological improvements in breeds, feeds, medication, and handling and processing of poultry. Feed use per pound of broilers produced, for example, has declined from over four to around two pounds, while mechanization and improvements in housing have reduced labor used per unit of output. Similarly, economies of size in mixing and bulk delivery of feed have increased efficiency in that area, while large scale processing plants that operate at close to capacity on a year around basis--together with marketing efficiencies--have reduced per unit processing costs.

As a consequence of improvements in production and processing, real prices of most poultry products have declined very significantly during the last half of the twentieth century. For example, while nominally broilers cost more today than in 1935, in real terms (with adjustments for inflation based on the consumer price index, 1967=100) their price has declined very significantly (Figure 3). In 1935, the real farm price was about 50 cents a pound while in 1998 it was less than 10 cents (the nominal or actual price was about 20 cents a pound in 1935 and 40 cents in 1998). A large share of the decrease in real prices occurred in the 1950s and 1960s when improved breeds of chickens became widely used and the integration process was being implemented. Although the decreases in real prices have continued, the declines have been much slower since the 1960s.

In recent years and especially during the last two decades, changes in patterns of production and consumption have occurred. Poultry production and consumption were seasonally oriented due to custom, production requirements, weather conditions, and related

Figure 2. U.S. Broiler and Turkey Production



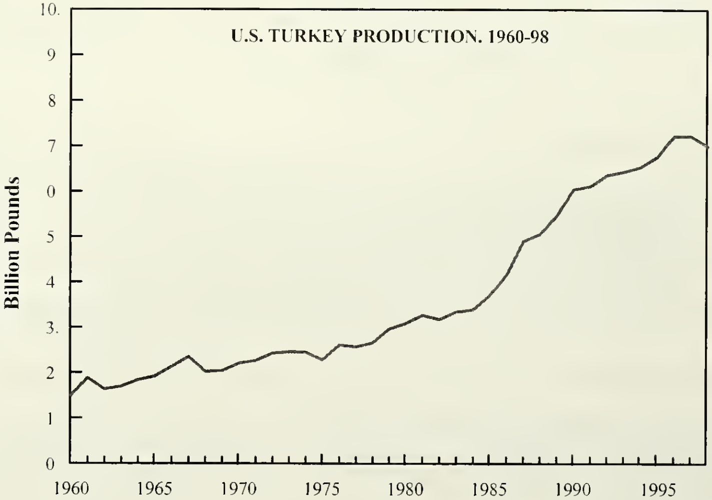
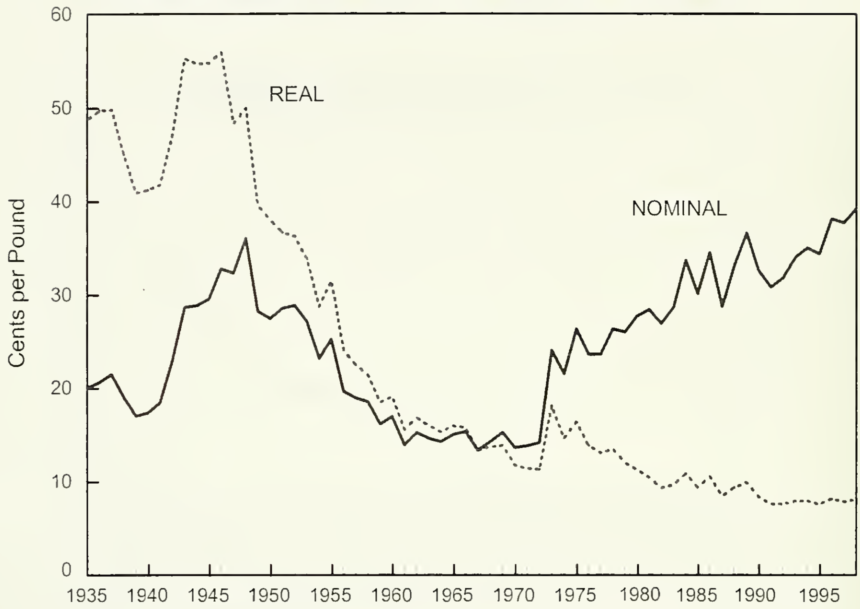


Figure 3. Nominal & Real Farm Prices of Broilers (1960=100)



factors. However, with modern production techniques there are no necessary seasonal patterns in production and year-around production is practiced to efficiently utilize expensive production and processing facilities. Thus, as shown in Figures 4 and 5, seasonality in production has become less important for both broilers and turkeys, although there is still a seasonal component in turkey consumption due to high demand during the Thanksgiving and Christmas seasons– many of the turkeys consumed during those seasons are processed, frozen and stored. The top panel of Figure 4 shows the variation around the trend for broilers, while the bottom panel shows how the monthly (seasonal) production pattern has declined and become less important. The top panel of Figure 5 indicates that for turkeys variation in production during the year has virtually

Figure 4. Trend and Seasonal Variation in Broiler Production

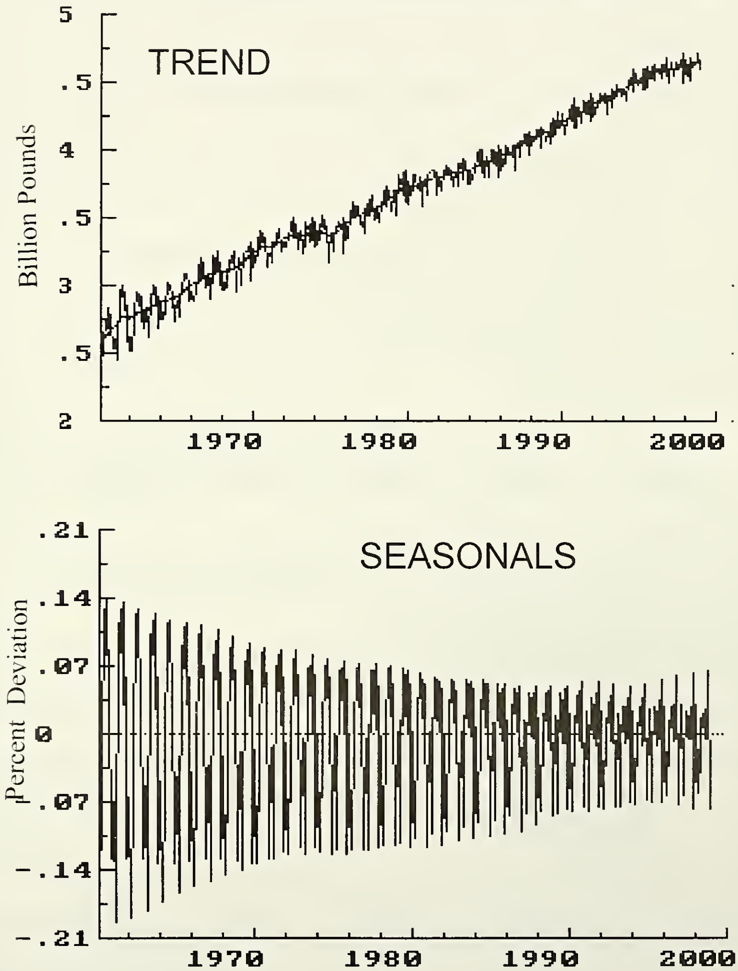
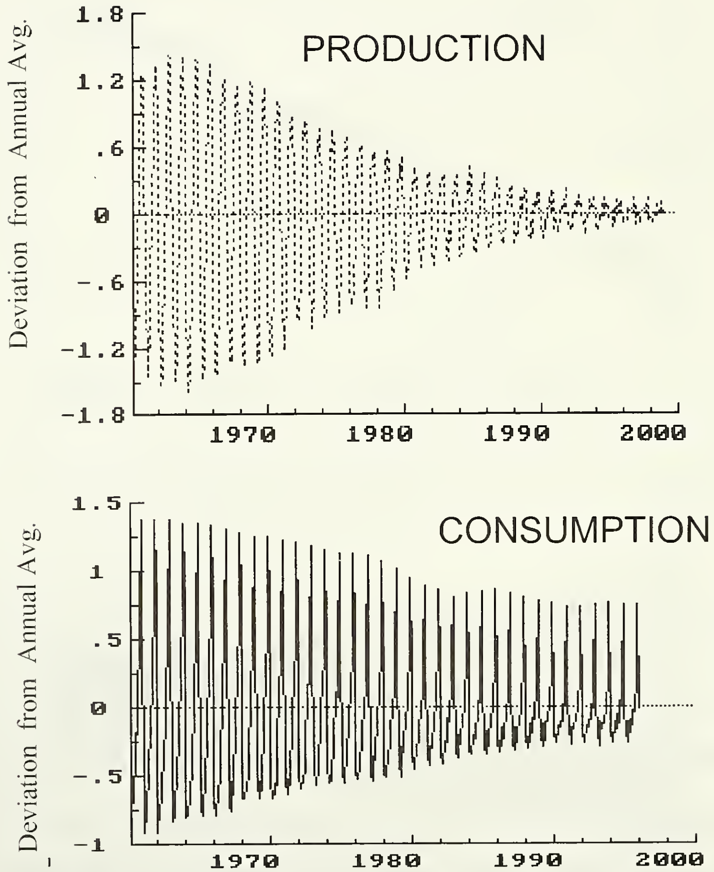


Figure 5. Seasonal Variation in Turkey Production & Consumption



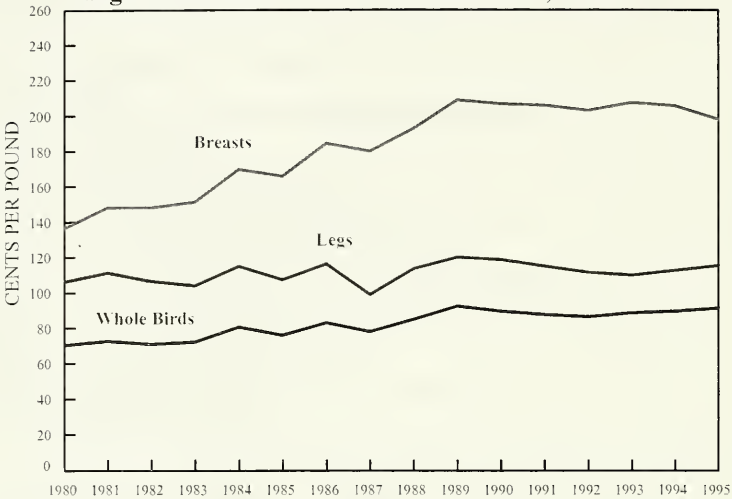
disappeared. The bottom panel show that turkey consumption is less concentrated than in the past although much of the consumption still occurs in November and December.

Another important change has been the trend in the U.S. for white meat cuts due to their lower fat content combined with greater health consciousness. As a consequence, there has been a shift from purchasing and consuming the whole bird to cut-up parts which are sold separately. Preferences for white meat parts has resulted in relatively large price differentials between the light and dark cuts (Figure 6), especially for broiler meat but also for turkey. For the latter, while whole birds are still demanded during the holiday seasons, a large share of turkey meat is consumed as parts with breast and darker meats sold separately. There has been a trend toward using more turkey in processed meats including sliced turkey breast as well as in products such as ground turkey, turkey bologna, turkey ham, hot dogs, sausage, etc.

There have been shifts in the areas where poultry are produced, with production becoming more concentrated. Perry, Banker and Green (1999) report that some 83 percent of the poultry farms are located in the Northeast, Midwest, Appalachian, Southeast and Delta regions with 70 percent of the value being produced in the Northeast, Appalachia, Southeast and Delta regions. However, California is also an important producer. Poultry farms in these regions tend to be large in terms of the value of the products produced but not in area per farm, averaging only 134 acres compared to around 400 acres for the average U.S. farm.

Most poultry production in the U.S. is carried out through large integrated processing operations that contract with farmers to produce the birds. There is considerable variation in the contracts used, but it is fairly typical for a farmer to own the land and buildings and to provide the labor, fuel, and related operating costs, while the integrator owns the birds, provides and transports the feed, and transports the birds to the processing plant. The farmer is usually paid a

Figure 6. Retail Prices for Broiler Cuts, 1980-95



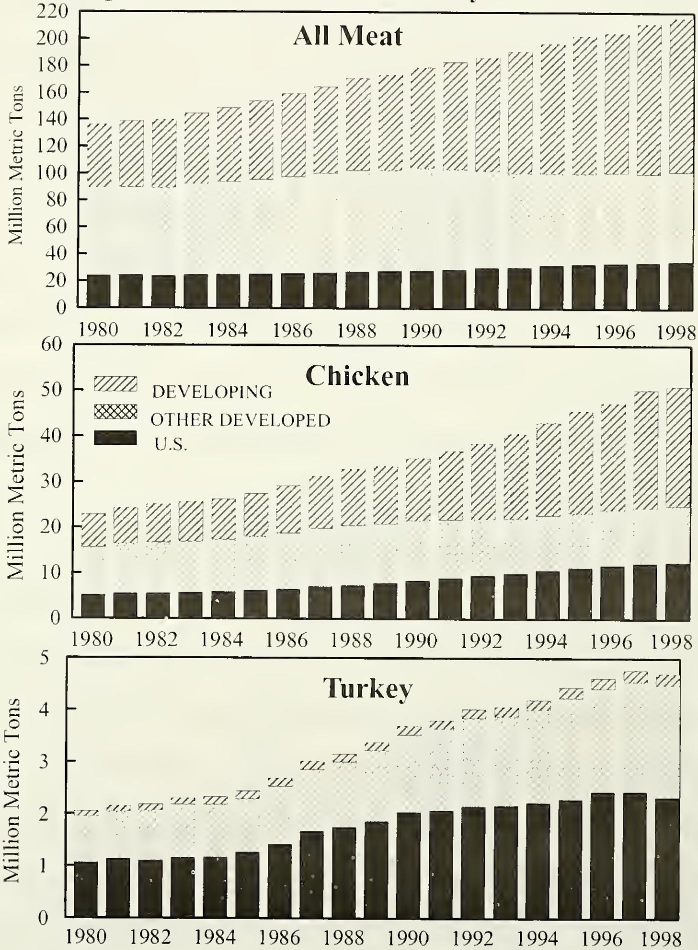
ee based on pounds produced and with incentives to promote efficiency. The integrator often employs field specialists to help assure quality of the products and efficiency in the operations.

World Poultry Industry

World production of all meats, chicken, and turkey for 1980-98 are shown in Figure 7 and Appendix Table D3. Production of all meat has increased about 57 percent, with most of the increase occurring in the developing countries; total meat production increased in the U.S., but has declined since 1990 in the other developed countries as a group. U.S. meat production grew by 45.8 percent between 1980 and 1998 while world production increased 58.8 percent; in the developing countries meat production increased 148 percent.

Chicken production in the world more than doubled in the 1980-98 time period with,

Figure 7. World Meat and Poultry Production



again, the largest increases taking place in the developing countries while substantial increases occurred in the U.S. but not in the other developed countries. The developing countries increased their share of chicken output from 31 percent in 1980 to 51 percent in 1998. The U.S. share rose slightly during this time, from 23.4 to 24.8 percent. The share of the other developed countries declined from 45 to 24 percent, although their total production increased by 18 percent. While Brazil, Thailand and China are among the larger producers in the developing country group, many other countries have increased poultry production very significantly.

Turkey production also doubled, but most of the turkeys are produced in the developed countries. While production also increased by over 100 percent in the developing countries, this was from a small base. The U.S. is the largest producer of turkeys with nearly one half of the world total; another 37 percent is produced in Europe, a large share in France which produces about one third of Europe's turkeys. Brazil produces some turkeys, but the developing countries as a group produce less than 5 percent of the world's turkey meat.

International Trade in Poultry Products

Historically, international trade in poultry products was not an important aspect of the industry, but as new technologies developed and poultry products became relatively inexpensive, international markets grew and now account for significant proportions of production. Rogers (1979) noted the growing importance of international markets at a time when only 4.5 percent of U.S. broiler and 2 percent of U.S. turkey production were being exported. An important factor affecting international trade is the relative ease with which poultry production technologies can be transferred to other countries (Vocke 1991). This has led to large increases in poultry production in many areas of the world; total poultry production, for example, increased from 136.4 million metric tons in 1980 to over 216.2 million in 1998, an annual growth rate of about

2.6 percent. In the developing countries, production nearly tripled during that period of time. Thus despite a large growth in production, trade increased because domestic producers could not meet the increased demands in many countries. Several European countries, Brazil, Thailand and China are important poultry producers and competitors of the U.S. in poultry exports.

Trends in quantities of U.S. broiler and turkey exports for 1960-98 are shown in Figure 8. Trade, like production, is dominated by broilers, which account for over 80 percent of the exports by volume, although often less in terms of value because turkey prices generally are higher than those for broilers and because the lower priced dark meat parts tend to be exported. In the 1960s, exports of both products were small relative to production, but exports of broilers began to grow in the mid-1970s and continued until 1982, when a worldwide recession caused exports to decline. However, growth in their exports resumed in 1985; they grew very rapidly in the 1990s, then slowed during the Asian crisis in 1998. Exports were enhanced by the availability of relatively inexpensive dark meat cuts due to U.S. preferences for white meat.

Turkey exports remained relatively low and fairly constant until about 1990, when they also began to grow at a rapid rate, rising from 53 million pounds in 1990 to 605 million pounds in 1997. Turkey exports were affected more severely by the economic crises of 1998-99 and declined considerably in 1998, dropping to around 446 million pounds. They declined further during the first six months of 1999. Turkeys are not as widely produced and consumed as broilers and their demand is subject to wider fluctuations than is broiler demand.

The major importers of U.S. produced broilers are Russia, Hong Kong, Mexico, Japan, and Canada; these five countries account for nearly three fourths of all U.S. broiler exports in 1997 and 1998. (Figure 9). Russia and Hong Kong together account for over half of the U.S. exports. Russian imports declined in 1998, but this was offset by a relatively large increase in

Figure 8. U.S. Broiler and Turkey Exports

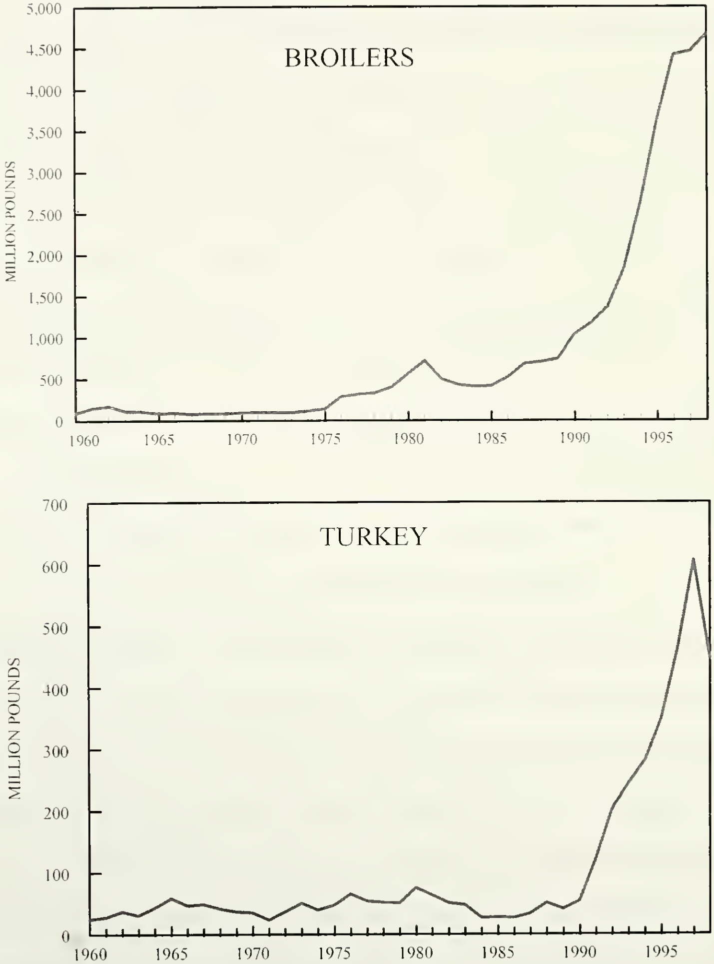
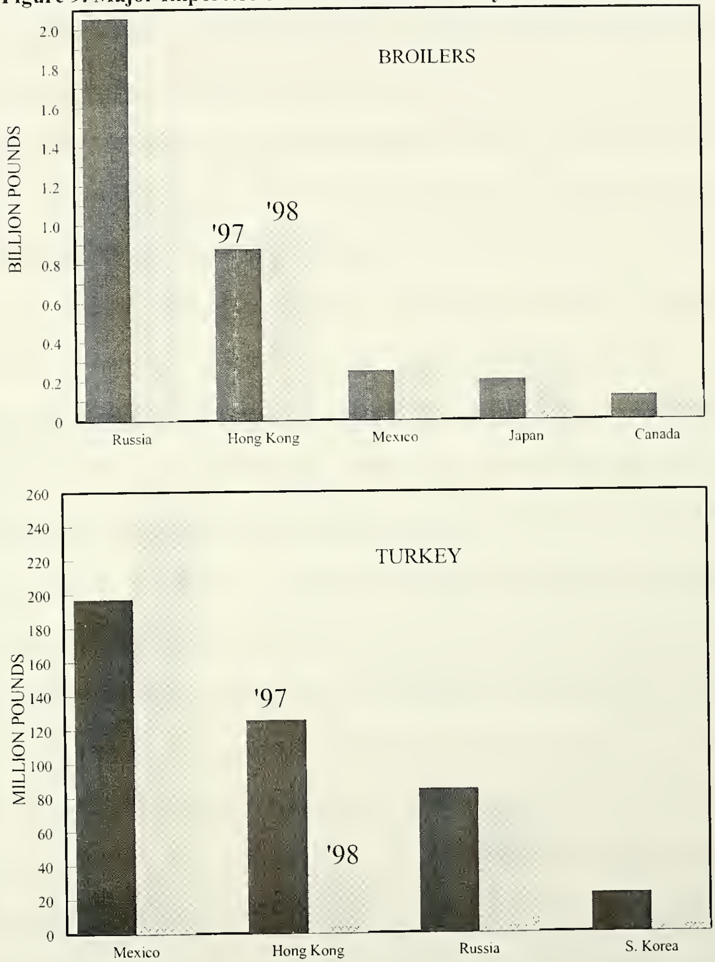


Figure 9. Major Importers of U.S. Broiler & Turkey Meat, 1997 & 1998



exports to Mexico and smaller increases to several other countries, including Hong Kong, Japan and Canada.

The major importers of turkey products are Mexico, Hong Kong, Russia and South Korea. Exports to Mexico have increased dramatically since the approval of the North American Free Trade Agreement (NAFTA). These are used mostly in processed meat products (lunch meats, sausages) and often replace pork. Despite a large drop in U.S. turkey exports in 1998, exports to Mexico continued to rise. Turkey exports to Russia grew after the collapse of the Soviet Union and a consequent decline in agricultural production as subsidies were reduced, although the growth was much less pronounced than for broilers. With the exception of Mexico, exports to all major importers declined in 1998.

Important competitors for U.S. broiler producers in international markets include Brazil, Thailand and the European Union (especially France and the Netherlands). Although production in those countries has grown, the share traded by the U.S. has remained relatively constant and the U.S. is still the dominant broiler producer and exporter. While the U.S. produces only about 16.5 percent of the world's total meat, it produces over one fourth of the poultry meat (25.1 percent in 1998) and 24.8 percent of chicken meat. The European Union's (EC-15) share of broiler production in 1998 was 12.5 percent, a decline from 19.3 percent in 1980. Brazil's share, however, increased, rising from 5.3 percent in 1980 to 7.5 percent in 1998. Other important producers include Thailand and China.

The U.S. exports about 37 percent of total chicken meat traded in the world but only 24 percent in terms of value exported, while the European Union exports 33 percent in volume and 46 percent in value. The differences are due to two factors: 1) the U.S. exports primarily lower priced dark meat parts so that the value is relatively low, and 2) large shares of the exports by

European Union members involve intra-country trading (among European countries) due to protectionist policies of the Common Agricultural Policy (CAP), which cause all poultry prices to be higher than in the U.S.

France is the largest exporter of turkey meat, although a large share of the French exports are within the European Union (just as a large share of U.S. exports are to Mexico under NAFTA). In 1998, France exported 355 thousand metric tons of turkey meat, about 48 percent of the country's production (Audran 1999). However, over two thirds of those were to other members of the European Union. The EU accounts for around 60 percent of turkey exports while the U.S. accounts for nearly 30 percent. As in the case of chicken, the relative values of U.S. exports are less than the volume, 19.9 percent compared to 29.7 percent; the average value per metric ton of U.S. exports in 1997 was $1,144 compared to $1,984 in the European Union. The explanation for this is similar to that for chicken, with European prices being higher due to protectionist agricultural policies. Brazil accounts for about 2 percent of total turkey exports. The proportion of U.S. exports in total world trade has declined, dropping from 43 percent to less than 30 percent between 1980 and 1998. While the share of EC-15 countries' exports increased from 40 to over 60 percent during the same period, a large proportion was intra-EU trade.

U.S. Competitiveness in International Markets

The relative costs of production for U.S. poultry and its major competitors in the international arena affect the ability of the U.S. to export the product, although competitiveness is determined by a more complex set of issues than just costs. Tariffs and non-tariff barriers including health and sanitary regulations, as well as consumer preferences, market shares, time of entry into markets, brands, diverse products and prices, trademarks and reputations, and

related factors have important implications for the competitive position of a country's agricultural products, as well as for those of individual exporters (Bishop et al. 1990; Henry and Rothwell 1995). Improved technology is a key to competitiveness and Vocke (1991) has shown that poultry technologies are relatively easily transferred, even to most of the less developed countries. While a modern poultry industry requires substantial investments to implement new technology, development of the necessary capabilities can be accomplished with training programs and through the use of skilled field workers.

Data on costs of production and processing for broilers in the six major exporting countries are shown in Table 1. The U.S. is intermediate in total costs, i.e., has lower costs than the European countries but higher costs than some of the developing countries. The Netherlands has the highest costs and Brazil the lowest costs. Thailand has slightly higher costs than Brazil while China has costs similar to those of the U.S.; costs in France are nearly as high as in the Netherlands. The U.S. has lower production but higher processing costs than Thailand and China, while Brazilian production and processing costs are both lower than in the U.S., although it has higher processing costs than Thailand and China. Both types of costs are substantially higher in France and the Netherlands than in the other four major exporting nations. France and the Netherlands export substantial amounts of poultry to Germany and other countries within the European Union where protectionism limits imports from nonmembers. Exports to nonmember countries are subsidized as well.

In addition to being affected by relative costs, international trade in poultry products is influenced by trade policies, including tariff and non-tariff barriers to trade erected by many countries. As a result of negotiation during the Uruguay round of the General Agreement on Trade and Tariffs (GATT), the World Trade Organization (WTO) was created in 1995. Under

its provisions non-tariff barriers are being eliminated through a process of tariffication, i.e., are to be converted to tariffs which will then be reduced through time. However, health and sanitation requirements can be used to restrict imports when they are based on scientific findings. The agreement has provisions for minimum market access under which signatories are required to allow imports equivalent to 3 percent—to increase to 5 percent—of their domestic consumption. For this tariff rate quotas (TRQ) are used; under these there are zero or very low

Table 1. Comparative Costs for Broiler Production, Selected Countries

	Industrialized Countries			Developing Countries		
Cost Item	U.S.A.	France	Netherlands	Brazil	Thailand	China
	Cents per Kilogram					
Chicks[a]	8.3	14.3	16.0	9.4	9.8	10.0
Feed[a]	36.8	57.1	55.2	35.9	51.5	42.9
Grower Payment[a]	8.8	19.2	25.8	5.3	6.3	5.8
Other Costs[a.b]	4.9	3	1.4	1.6	3.7	2.4
Total at Plant[a]	58.8	93.6	98.4	52.2	71.3	61.1
Meat Cost at Plant[c]	76.2	123.6	129.9	68.9	81.4	94.2
Processing Costs[c]	28.9	35.0	33.5	16.5	11.8	12.4
Total Costs[c]	105.0	158.6	163.4	85.4	93.2	106.5

Source: Henry and Rothwell, 1995
[a] Liveweight basis
[b] Veterinary, medication, transportation, administrative fees
[c] Ready to cook basis

tariffs for imports made within the quota, but higher tariffs for those in excess of the quota. In the European Union, the in-quota most favored nation (MFN) average tariff on poultry meats is 11 percent and the out-of-quota MFN rate is 43.6 percent. Tariffs also vary with the type of product, whole birds compared to parts, light meat compared with dark, livers, feet, etc. Turkeys, which are not produced in significant quantities in many countries, tend to have lower

tariffs than broilers. Often there is tariff escalation with increases in the stage of production, such that more highly processed products face higher tariffs than unprocessed or less processed products–this escalation is to encourage imports of less processed products which are then processed internally to increase domestic employment and income.

Non-tariff barriers, including prohibitions, quotas, import licences, health and sanitary regulations, environmental requirements, and other restrictions, are still used despite the WTO requirement for tariffication of non-tariff barriers, i.e., the conversion of non-tariff barriers into tariffs. Health and sanitary requirements are permitted where there is a scientific basis for their utilization. Thus, poultry diseases (such as avian influenza or Newcastle disease) or the existence of salmonella and other organisms on poultry meat may be used as bases for prohibiting imports; some countries, for example, have zero tolerances for salmonella which, effectively, prohibits imports. Because it is difficult to separate genuine concerns about health and safety from restrictionist policies, these types of barriers are difficult to resolve and often become issues for the trade dispute settlement process.

Export subsidies are another policy used to increase export and competitiveness; these have been especially important for increasing European exports. In 1996, for example, prices for exports from France to countries within the E.U. were substantially higher than those to other countries (FAS 1997). For frozen whole chickens the average price per kilogram to E.U. countries was 8.56 French Francs (FF) while they were 6.38 FF for exports to the Middle East and 6.68 for Russia. Frozen chicken and turkey pieces had even larger disparities, but much of those differences were due to the types of products exported to the different areas. However, WTO provides for a reduction (and eventual elimination) of export subsidies and by 1998 much of the differences had been eliminated (FAS 1999).

PART II. ECONOMETRIC ANALYSIS OF POULTRY TRADE

International trade in poultry products in the 1990s has been characterized by a very strong growth trend with extensive fluctuations around that trend. To help develop a more complete understanding of these fluctuations, econometric techniques are used, principally those for time series analysis. This requires that time series data be employed which possess a sufficient number of observations for reliable estimates of the parameters of the models. Because production, marketing and trade in poultry are dynamic phenomena in which the parameters may vary through time, the models employed must represent stochastic behavior. These allow parameters to vary over time so that they are representative of the present rather than the average of the model's past history.

Econometric Methodology for Poultry Trade Models

In this section, the nature of the econometric methodologies employed including time series analysis, market model analysis, and structural time series analysis are explained briefly. These techniques are used to help analyze and interpret production and trade patterns for poultry. Interpretation and explanations of these problems for broiler and turkey exports as well as for disaggregated poultry product exports are covered in the following sections.

Time Series Analysis

Poultry production and trade variables have been shown to fluctuate considerably over time, displaying trends, cycles (mostly of a stochastic nature), seasonal variation, and irregular (random) movements. Such behavior was confirmed early by Rausser and Cargill (1970) who identified factors that caused poultry industry phenomena to change over time, i.e., technology, vertical integration, etc. Time series analysis normally begins by decomposing each variable into its trend, seasonal, and cyclical components. At this point, transformations of the data for

each variable are performed, so that trends are removed and the cyclical or irregular movements can be observed. Then, the behavior of each component can be evaluated for significance using appropriate statistical tests.

Market Model Analysis

The behavioral patterns of the poultry production and trade variables can be further analyzed by analyzing covariation in their behavior. This is accomplished by analyzing the factors which underlie their demand, supply and trade patterns using commodity market modeling methods in the time domain. This approach typically explains production, consumption, export and price variables on the basis of other related market variables and of macroeconomic variables such as gross domestic product and consumer prices.

An example of how a poultry market model can be specified in this regard begins with the concept of a market balance sheet that equilibrates production and imports with consumption and exports, including an adjustment for stock changes. By neglecting market imperfections, the structure of the market is assumed to be competitive and price determination follows from the equilibrium of demand and supply. The corresponding model consists of a number of simultaneously related econometric regression equations, each explaining a single market or sector variable.

The standard commodity model (SCM) explains market adjustments according to interactions between demand, supply, trade and inventories, see, e.g., Labys (1973) or Lord (1991). The general form of this model is:

$$D_t = d(D_{t-1}, P_t, PC_t, A_t, T_t) \tag{1}$$
$$Q_t = q(Q_{t-1}, P_{t-\theta}, N_t, Z_t) \tag{2}$$
$$P_t = p(P_{t-1}, {}_{\Delta it}, T, B) \tag{3}$$
$$I_t = I_{t-1} + Q_t + M_t - D_t - X_t \tag{4}$$

Poultry demand (D) is explained as being dependent on prices (P), income or processing activities(A), prices of one or more meat substitutes (PC), and possible technological influences (T) or consumer tastes. Accordingly, poultry supply (Q) depends on lagged prices, input factors (N), and policy (intervention) variables (Z). Poultry exports are a function of poultry prices and consumer incomes in other countries. Poultry prices can be explained by changes in inventories (ΔI), tariffs (T), and nontariff trade barriers, (B).

A presently important feature of this approach is that explanatory factors of poultry exports and foreign poultry imports can be included. For example, the demand for poultry exports (X) to other countries can be explained as follows:

$$X_t = x(AW_t, PW/P, ER) \tag{5}$$

where AW reflects incomes or processing activities in the rest of the world, PW/P reflects poultry prices in the rest of the world relative to U.S. prices, and ER is an explicit exchange rate influence. These exports can be disaggregated to reflect import demands (M) in individual foreign countries (i):

$$M_t = m(S, AW_i, PW_i/P, PC_i, {}_{MSi}) \tag{6}$$

where S represents shifts in the U.S. supply, PC is the price of meat substitutes in the foreign country, and MS is the market share in that country (see Leamer and Stearn 1970; Liu et al. 1993). Model closure is attained through an identity equation. Empirical applications of this type of model require additional specification, determination of estimation methodologies, and simulation procedures.

Structural Time Series Model Analysis

A problem encountered with econometric regression analysis is that the required data transformations enable one to model just one time series component (such as cycles) at a time or

for each representation. This approach, thus, has less potential to explain or to forecast the more complex components of a time series variable. In the case of the poultry variables, the time series variation has been shown to be extremely complex and, thus, warrants a modeling approach that would combine not only several time series components but also important market and macroeconomic variables. Examples of previous studies of such cyclical and seasonal variations for poultry variables include Chavas and Johnson (1982), Goodwin (1994), Meadows (1970) and Rausser and Cargill (1970).

The modeling approach used is structural time series analysis (STS). These models combine the trend, seasonal, cyclical and irregular or stochastic components into a single econometric regression which also includes other market, macroeconomic variables, and policy intervention variables. For a complete explanation of this type of model, see, e.g., Harvey (1989,1994) or Harvey et al. (1986). A brief explanation of the STS models is given in Appendix A. Variations of these models are applied first to broiler exports, then to turkey exports, and finally to the study of exports of disaggregated poultry producst such as cut-up chicken and turkey pieces.

For empirical estimation, the STS model described above is defined empirically to be of the form:

$$y_t = \mu_t + \psi_t + \gamma_t + \epsilon_t \tag{7}$$

where μ_t is the trend, ψ_t is the cycle, γ_t is the seasonal, ϵ_t is the irregular component, and t = 1, 2, ...T. All four components are stochastic and the disturbances driving them are mutually uncorrelated. The trend, seasonals and cycles are all derived from deterministic functions of time and reduce to these functions as limiting cases. The irregular component, ϵ_t, is white noise.

The structural model may be extended by adding exogenous explanatory variables, such

as incomes in foreign nations or interventions, to the right hand side of (7) giving:

$$y_t = \mu_t + \psi_t + \gamma_t + \sum_{j=1}^{k} \delta_j x_{jt} + \lambda w_t + \epsilon_t \,, \tag{8}$$

where x_{jt} is the value of the jth explanatory variable at time t, δ_j is its coefficient, and w_t is an intervention variable.

This framework can be used to estimate the effect of a policy intervention, such as the imposition of import quotas, on poultry imports from the U.S. at the time the intervention is imposed. For this estimate, it is assumed that the effect of the intervention occurs instantaneously and leads to an immediate change in the level of the series (Harvey and Durbin 1986, p. 190). In the simplest case, where the response is instantaneous and constant, w_t is a standard dummy variable.

The export structural time series model can be fitted efficiently by powerful, but straightforward, general techniques. The key to effectively these techniques is that the model can be put into state space form and then handled routinely by the Kalman filter. In its general univariate form, the state space model consists of the following two equations:

$$y_t = Z'_t \alpha_t + \epsilon_t \tag{9}$$

called the measurement or observation equation, and

$$\alpha_t = T_t \alpha_{t-1} + \eta_t \tag{10}$$

called the transition or state equation. Where, t = 1, 2, ...T, y_t is the observation of interest, Z_t is a non-stochastic vector, α_t is an m x 1 state vector, T_t is a non-stochastic m x m matrix, and ϵ_t,

and η_t are (normally, independently distributed) NID(0, $\sigma^2 h_t$) and (0, $\sigma^2 Q_t$) disturbances, where h_t is a scalar.

Sources of Data

Annual, quarterly and monthly data are available for U.S. broiler and turkey production, demand, inventories, exports and prices (data on the poultry industry and trade are given in Appendix D). However, only annual data are available for many other countries and these are used for broiler import demand equations for Canada, Hong-Kong, Japan and Mexico, as well as for Brazilian broiler exports and export prices. Thus, annual data are used for analyzing import demands for U.S. broilers by importing countries. Variables expressed in monetary units are deflated by appropriate gross national product (GNP) deflators. All nominal prices are deflated by the appropriate consumer price indices (CPI) of the U.S. and poultry importing countries. Demand and import variables in the model are expressed as per capita.

Sources for the quarterly broiler, turkey, poultry, beef and pork data are publications by the ERS-USDA, including the serial publications, *Livestock and Poultry Situation and Outlook* and *Poultry Outlook*. The U.S. CPI, population and per capita income variables were obtained from the *Survey of Current Business* published by the US Department of Commerce. Data for variables in the importing countries were from the following sources: production and import prices are from *Production and Trade Yearbooks* of the Food and Agricultural Organization (FAO) of the United Nations, and GNP deflators from *World Tables* of the World Bank, and exchange rates and price indexes from *International Financial Statistics* of the International Monetary Fund.

Monthly data for the 1970-98 period are used for estimating and testing the turkey models. The sources of these data are U.S. Department of Agriculture publications, primarily

the *Poultry Yearbook* for 1970-95 data and various issues of the *Livestock, Dairy and Poultry Situation and Outlook* reports for the subsequent years; with all data obtained from the internet data base maintained at the Mann Library, Cornell University. The model is estimated using 1970-95 data, with the 1996-98 set reserved for testing the forecasting capabilities of the model. The data were converted to natural logs for the estimation. The Stamp (Structural Time Series Analyser, Modeller and Predictor) program is used to estimate the model (Koopman et al. 1995).

Empirical Broiler Model

The empirical model used for this analysis consists of fourteen equations, one of which is an identity. The three major components of the model are supply side equations (supply, demand, inventories, and export demand functions), price linkages (prices of broilers, beef, pork, turkey, and feed functions), and import side equations (import demand functions for Japan, Hong Kong, Canada and Mexico). The complete model is reported in Kapombe (1997) and Kapombe and Colyer (1999); variable definitions are given in Appendix B. Only the trade related equations, described in the following two paragraphs, are used for this analysis.

The broiler export supply (QBX) equation is specified as a function of the lagged one quarter wholesale price (WPB), lagged one quarter real exchange rate (RSD), and lagged one quater production (QBP):

$$QBX_t = \mu_t + \gamma_t + a_{15}WPB_{t-1} + a_{16}RSD_{t-1} + a_{17}QBP_{t-1} + \epsilon_{4t} \qquad (11)$$

The exchange rate between the dollar and the Japanese yen is used as a proxy for the exchange rate with other countries. It is hypothesized that an increase in the value of the dollar make U.S. exports more expensive, reducing broiler demand abroad.

Import demand equations are included for the major markets: Japan, Hong Kong, Canada, and Mexico (Russia and China were omitted due to an insufficient number of years):

$$BID_{it} = \mu_{it} + \beta_1 BID_{it-1} + \beta_2 RFOBPBr_{it} + \beta_3 RFOBPB_{it} + \beta_4 RFOBPP_{it} + \beta_5 RYE_{it} + \beta_6 PCBP_{it} + \beta_7 RSD_{it} + \epsilon_{it} \quad (12)$$

(i = 1, 2, 3, 4 for Japan, Hong Kong, Canada and Mexico; in Table 2, the broiler import equations are JAUSBID for Japan, HOUSBID for Hong Kong, CAUSBIOD for Canada, and MEUSBID for Mexico)

The import demand for U.S. broilers (BID) in the ith country (i = 1, 2, 3, 4) is specified as a function of the one quarter lagged dependent variable (BID), the real FOB prices of broilers (RFOBPBr), beef (RFOBPB) and pork (RFOBPP) imported by country i, the real per capita gross domestic product of the importing country (RYE), per capita production of broilers in the ith importing country (BCBP), and the real exchange rate between the currency of the ith importing country and the U.S. dollar (RSD), i.e., the units of the foreign currency that can be purchased with one dollar. Binary variables are included in the Mexican and Canadian import demand equations to account for trade intervention policies in those countries.

The results of employing maximum likelihood methods to estimate the coefficients and related multipliers are presented in Table 2. In initial tests of the model some variables, e.g., per capita income in the importing country, were found to be statistically non-significant and were omitted from the final model.

Broiler Exports

Impacts of changes in broiler production and prices of broilers and turkeys on broiler exports appear to be important explanatory variables. The elasticity of exports with respect to broiler prices, pork prices, and broiler production were -0.1, 0.75 and 1.2 percent, respectively. Broiler exports appear to be very elastic in their response to changes in broiler production. This

Table 2. Maximum Likelihood Estimates for Trade Equations in the Broiler Export Model[a,b]

$QBX_t = 4.25\mu^{*} - .1WPB_{t-1}^{*} + .75RSD_{t-1}^{**} + 1.2QBP_{t-1}^{*} + \hat{E}_t$

(.16)(.21) (.35) (.71)

Std. Error = .16 N = 1.66 Q(10) = 8.57 H(30) = .61 $R^2_D = .23$ $R^2_S = .15$ DW = 1.91

$JAUSBID_t = 14.9\mu^{***} - .96DRJP_t^{***} - 1.2JAQBPt^{*} + .32JAUSBID_{t-1}^{***} + \hat{E}_t$

(.36) (.29) (.67) (.07)

Std. Error = .11 N = .23 Q(9) = 3.54 H(7) = 1.06 $R^2_D = .74$ DW = 1.51

$HOUSBID_t = 13.36\mu^{***} - .56HORSD_t^{*} - .51HOFOBP_t^{**} + .53LPHOUSBID_{t-1}^{***} + \hat{E}_t$

(.72) (.3) (.21) (.05)

Std. Error = .088 N = .21 Q(8) = 8.37 H(7) = .33 $R^2_D = .86$ DW = 1.5

$CAUSBID_t = 6.06\mu^{***} + .64CAFOBIPt^{***} + .48CAUSBID_{t-1}^{***} - .38W_{t75}^{*} + \hat{E}_t$

(.56) (.22) (.06) (.2)

Std. Error = .151 N = 1.06 Q(9) = 10.54 H(7) = .42 $R^2_D = .735$ DW = 1.68

$MEUSBID_t = 11.92\mu^{***} - .58MERSD_t^{***} - .72MEFOBP_t^{***} - 1.22W_{t83}^{***} + \hat{E}_t$

(1.05) (.14) (.17) (.17)

Std. Error = .152 N = .293 Q(8) = 8.11 H(7) = .34 $R^2_D = .85$ DW = 2.13

[a] values in square brackets are standard deviations for the state and explanatory variable coefficients at the end of period. *** significant at 1% level, ** significant at 5% level, and * significant at 10% level. N: the Jarque and Bera statistic for testing normality, which follows asymptotically a χ^2 distribution with two degrees of freedom under the null hypothesis. Q(P): the Box-Ljung statistic, based on the first P residual autocorrelations. H(m): a test for heteroscedasticity (unequal variances). R^2: not very useful as a measure of goodness of fit when analyzing time series that exhibit strong upwards or downwards trends and/or seasonal cycles. Harvey (1991) proposes new coefficients of determination: R^2_D: substituting the observations by their first differences, if the series presents seasonal behaviour; R^2_S : substituting the observations by the first differences of the series around the seasonal means.
The reduced form is also used to generate the dynamic multipliers associated with the exogenous variables.

[b] The equations in this table are the results of a final model which contains only the statistically significant variables.

Is an interesting result because it suggests that the broiler export market is positively related to increases in the level of production. while responding negatively to increases in broiler prices. Finally, broiler exports are responsive to turkey prices, with an elasticity of 0.75.

Broiler Imports

Japanese demand for U.S. broiler imports is negatively influenced by the exchange rate (SDRJP) and per capita Japanese broiler production. The exchange rate plays an important role in the export of U.S. broilers to Japan. Import demand decreases by 0.96 percent with a 1.0 percent increase in the yen-dollar exchange rate. Japanese production of broilers is a significant determinant of import demand. A one percent increase in Japanese production of broilers will decrease broiler imports by 1.2 percent. This result is consistent with the presence of a strong association between production and import demand for U.S. broilers over the time used in this study. Other variables were not significant.

Hong Kong's demand for U.S. broiler imports is negatively influenced by the exchange rate and broiler import price. One percent increases in the Hong Kong-U.S. dollar exchange rate and broiler import price decrease imports by .56 and .51 percent, respectively

Canadian demand for U.S. broiler imports is positively influenced by beef import price and negatively influenced by the trade policy measures taken by the Canadian Chicken Marketing Agency to decrease imports. A one percent increase in beef import price will increase Canadian imports of U.S. broilers by 0.61 percent. The intervention variable for the 1973 imposition of a Canadian import quota for U.S. broiler imports was negative (-0.37) and statistically significant.

Mexican demand for U.S. broiler imports is negatively influenced by the exchange rate, broiler import prices, and the trade policy measures taken after 1982. Mexican tariff rate quotas and broiler import prices play a significant role in the import of U.S. broilers by Mexico. A one percent increase in broiler import price decreases imports by 0.72 percent. Also, a one percent increase in the peso-dollar exchange rate will decrease imports by 0.58 percent. The imposition

of the tariff rate quotas in 1983 has decreased Mexican imports of U.S. broilers; although liberalizing its trade policy in 1982, Mexico kept high trade tariff rate quotas on poultry imports from the U.S.[1]

Other Significant Findings

The demand for broiler exports is somewhat less price inelastic, with a price elasticity of -0.1. However, within the individual importing countries except in Japan where the price variable was not statistically significant, demands were considerably less inelastic with the price elasticities being -0.56 in Hong Kong, -0.64 in Canada, and -0.72 in Mexico.

Dynamic Characteristics

Expressing the model as a first order, linear difference equation system permits studying the dynamic behavior of the model with standard procedures of linear system analysis. Table 3 shows the dynamic (impact, interim and total) multipliers associated with those changes for the current period and for lag periods extending from one to two years for the annual models and one to four quarters for quarterly models. Given the ability of broiler producers to adjust production (it takes 7 to 8 weeks to produce a 3.5 to 4.5 pound broiler) in response to changing profit conditions, these multipliers (calculated after 4 quarters or 2 years) represent a fairly long and smooth adjustment process once the initial shocks are over. This is consistent with the study by Goodwin, Madrigal and Martin (1996, p. 37).

Examination of the results shown in Table 3 suggest that in the long run: (1) turkey prices impact on broiler inventories, exports and prices of broilers and pork; (2) broiler exports

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[1]While NAFTA appears to be having significant impacts on exports, the time since its implementation has been too brief to include it in this analysis.

impact on the quantity of broilers demanded (disappearance); (3) real exchange rates impact on broiler wholesale prices; and (4) broiler supplies impact on broiler exports.

Multipliers for Broiler Exports A sustained one percent increase in the yens per dollar real exchange rate would cause Japanese-U.S. broiler imports demand to decrease by 1.42 percent in the long-run (total effects), compared to 1.1 and 0.45 percent in the current and after one year, respectively. Also, a sustained one percent increase in Japanese broiler production would cause Japanese–U.S. broiler import demand to decrease by 1.7 percent in the long-run, compared to decreases of 1.36 and 1.1 percent in the current period and after one year, respectively.

Multipliers for Broiler Imports A sustained one percent increase in the real exchange rate would cause Hong Kong's demand for U.S. broiler imports to decrease by 1.5 percent in the long-run (total effects), compared to a decrease of 0.74 and 0.42 percent in the current period and after one year, respectively. A sustained one percent increase in the broiler import price would cause Hong Kong-U.S. broiler imports demand to decrease by 1.2 percent in the long-run (total effects), compared to decreases of 0.67 and 0.50 percent in the current period and after one year, respectively.

A sustained one percent increase in the Canadian beef import price would cause Canada's imports of U.S. broilers imports to increase by 0.76 percent in the long-run (total effects), compared to an increase of 0.39 and 0.36 percent in the current period and after one year, respectively.

Table 3. Dynamic Multipliers for Selected Endogenous and Exogenous Variables

	Exogenous Variables								
	Impact[a]	Interim[b]	Total[c]	Impact	Interim	Total	Impact	Interim	Total
Endogenous Variables	Wholesale Price of Broilers			Turkey Price			Pork Price		
U.S. Broiler Exports	-0.163	-0.135	-0.214	0.520	0.270	0.890	0.920	0.0520	1.760
	Real Exchange Rate			Japanese Broiler Production			Hong-Kong Broiler Price		
Japanese Broiler Imports	-1.10	-.450	-1.42	-1.36	-1.10	-1.70	-	-	-
Hong-Kong Broiler Imports	-.740	-.420	-1.50	-	-	-	-.670	-.500	-1.200
	Canadian Beef Import Price			Canadian Import Quotas					
Canadian Broiler Imports	+.390	+.360	+.760	-.420	-.220	-.550	-	-	-
	Mexican Tariff Rate Quotas			Real Exchange Rate			Mexican Broiler Import Price		
Mexican. Broiler Imports	-1.320	-1.20	-1.880	-.740	-.260	-.840	-.640	-.250	-.970

[a] The impact multipliers refer to the current-period (zero-period lag) effect of a change in the exogenous variable on the endogenous variables.
[b] The interim multipliers refer to a one year-period lag effects of changes in the exogenous variable on the endogenous variable.
[c] The total multipliers refer to the situation where the increase in the exogenous variables is sustained for a two year-period lag.

A sustained one percent increase in the peso-dollar real exchange rate would cause Mexico's broiler import demand to decrease by 0.84 percent in the long-run (total effects), compared to 0.74 and 0.26 percent decreases in the current period and after one year, respectively. Also, a sustained one percent increase in the broiler import price would cause Mexico's imports of U.S. broilers to decrease by 0.97 percent in the long-run (total effects), compared to a decreases of 0.64 and 0.25 percent in the current period and after one year, respectively.

Implications

The findings reported for broiler trade can be translated into the following policy implications:

(1) The volume of broiler purchased by importers has been found to be responsive to prices and somewhat irregular in nature, making it difficult for individual processors to plan to ship from normal production. Providing a consistent export supply is essential in planning for growth of broiler exports. One possibility for increasing exports is to prepare for meeting the increasing but variable international demand by investing in cold storage facilities. This would allow the industry to increase broiler inventories, reduce shipment bottlenecks, and respond more effectively to export market volatility.

(2) The possibilities of reducing or eliminating tariff rate quotas on imports, under NAFTA negotiations with Mexico and Canada, should benefit the U.S. broiler industry by producing more stable and reliable product flows. It is expected that trade liberalization will play an increasingly important role in the continued expansion of the U.S. broiler industry.

(3) The long-run own-price elasticity of exports for U.S. broilers is less than one and very low (-0.1), implying that the lowering of prices is not an effective way to increase the value of U.S. broiler exports. Strengthening the import demand for U.S. broilers through such means as the USDA's Market Promotion Program and efforts by broiler processing companies could be a better marketing strategy for maintaining or increasing the current level of U.S. broiler exports. Finally, U.S. government policy of providing an export promotion subsidy in line with recent GATT negotiations is a potential strategy to promote broiler sales in international markets; poultry promotion subsidies could be increased because current levels of subsidies are less than the 1986-90 base.

(4) Since approximately two thirds of the cost of producing poultry can be attributed to feeds, feed grain and soybean price policies can have important effects on the poultry market. Policies contained in the 1996 Federal Agricultural Improvement and Reform Act (FAIR), which decoupled agricultural subsidies from production, were expected to cause grain prices and, hence, poultry production costs to increase. However, increased production combined with unfavorable changes in world demand resulted in feed grain and soybean prices falling precipitously in 1998 and 1999. The consequent reduction in broiler production costs, however, was offset by decreases in demand for poultry products that resulted, at least in part, from declines in demand due to the Asian and Russian economic crises.

STS Turkey Trade Analysis

In this section, U.S. turkey exports are analyzed based on the time series component approach of the STS model That is, the models are formulated directly in terms of trend, seasonal, cyclical and residual (irregular) components.

Turkey Model

The STS model defined earlier is specified as follows:

Exports = Trend + Seasonal + Cycle + Explanatory Variables + Irregular.

Because the turkey industry is dynamic and many changes have occurred in recent years, the model components are entered in stochastic form, i.e., their coefficients are allowed to vary over time; the trend variable can have both level and slope coefficients. The explanatory variables include the real U.S. wholesale turkey real price lagged one month (PRICE), lagged turkey production (PRODLAG), the poultry trade weighted exchange rate (XRATE), the real price for broilers (BROILPR), and an intervention (dummy) variable for the end of the cold war (COLDWAR), 0 for years 1970-88, 1 for 1989-98. Following normal demand concepts, the price variable is expected to have a negative sign; the wholesale price is used becausse that is where price formation occurs in the integrated poultry industry. Increased poultry production in one period should lead to increased exports in subsequent periods; while it was anticipated that a one period (month) lag would be reasonable, one, two and three month lags were tested. Increases in the exchange rate make U.S. products relatively more expensive and, therefore, are expected to have a negative effect on exports. Broilers can be a substitute for turkey and, thus, the sign for this variable should be positive; Kapombe (1997) found a relationship between turkey prices and broiler exports. Finally, the end of cold war resulted in an increase in exports of poultry to Russia and other former Soviet Union countries and could be expected to have produced structural changes that might not be captured by the trend variable.

The initial estimation of the model indicated that the cyclical component greater than seasonal frequency was not relevant (although examination of the raw data had indicated that there might be a cyclical effect) and that broiler prices did not have a statistically significant

effect. Furthermore, it was found that a three month lag in turkey production was significant while the other lag lengths were not. Thus, the model was adjusted and re-estimated without the cyclical component, broiler prices, and one and two month production lags. The diagnostics for the final model generally were very good, suggesting strong validation.

Turkey Export Model Results

The results for the final model are given in Table 4. The trend level is significant but the slope is not. This is for a stochastic trend and indicates that, at the end of the model (1995), the growth rate for exports is 7.28% per year (2.7 million pounds). While there has been an upward trend in turkey exports, this did not become pronounced until the 1990s when both the total exports and the percentage of production exported increased. As indicated previously, the end of

Table 4. Estimated Coefficients of Final State Vector

Variable	Coefficient	R.M.S.E.	t-value	Probability
TrendLevel	17.121	3.8219	4.4797	[0.0000]*
TrendSlope	0.00606962	0.00655189	0.926391	[0.3550]
Sea_1(Jan)	.0530058	0.0416240	1.2734	[0.2039]
Sea_2 (Feb)	-0.201759	0.0273849	-7.3675	[0.0000]*
Sea_3 (Mar)	.0106723	0.0207421	0.514523	[0.6073]
Sea_4 (Apr)	-0.0651084	0.0211776	-3.0744	[0.0023]*
Sea_5 (May)	.0211504	0.0195532	1.0817	[0.2803]
Sea_6 (Jun)	-0.0707695	0.0190435	-3.7162	[0.0002]*
Sea_7 (Jul)	0.0320816	0.0186127	1.7236	[0.0858]***
Sea_8 (Aug)	-0.0397388	0.0186234	-2.1338	[0.0337]**
Sea_9 (Sep)	0.0496311	0.0186326	2.6637	[0.0081]*
Sea_10 (Oct)	0.00661723	0.0184349	0.358952	[0.7199]
Sea_11 (Nov)	0.00695860	0.0130149	0.534665	[0.5933]
XRATE	-1.7706	0.777836	-2.2763	[0.0235]**
PRODLAG3	0.218807	0.0676623	3.2338	[0.0014]*
PRICELAG1	-0.36356	00.190585	-1.9076	[0.0574]***

* Significant at 1%; ** Significant at 5%; *** Significant at 10%.

the cold war resulted in increased exports of turkey meat to Russia. Thus, it was hypothesized that structure of exports might have changed and that an intervention (dummy) variable would be needed to capture this effect. However, the dummy variable was not significant, indicating that the stochastic trend component together with the explanatory variable were adequate in modeling this aspect of turkey exports.

Overall, the seasonal component was highly significant [chi square(11)=100.8 (prob. =0.0000)] with six significant coefficients for the individual months. Exports tend to rise slowly from January through November, drop slightly in December, and then decline sharply in January. The seasonal component, however, is fixed, meaning that it did not change significantly over the 1970-95 time period. The significance and fixity of the seasonal component for exports contrasts sharply with the changes in seasonality of domestic production and consumption. Seasonality in production was marked in the 1970s, but declined throughout the study period and had disappeared by the end of the study. While turkey production now takes place year round, consumption still has a seasonal component, although it is less pronounced than in the past, i.e., the seasonal component for per capita consumption was still significant at the end of the period. The seasonal variation by month, expressed as the percentage deviations from the annual totals, are shown in Figure 10. Examination of this graph of the seasonal component, however, indicates that the amplitude of the seasonals has declined since the early 1970s. Trend and seasonal components also are found for the exports of whole turkeys and turkey pieces; both are more significant for whole turkey exports.

The three explanatory variables in the final model, based on those that were statistically significant in a test run of the model, were the real wholesale turkey price lagged one month at 10 percent, the poultry trade weighted exchange rate at 5 percent significance, and production

Figure 10. Seasonal Distribution of Turkey Exports

lagged three months at 1 percent significance. Price was inelastic (-0.36), indicating that a one percent increase in prices causes exports to decline by 0.36 precent. Exchange rate increases have a strong negative effect on exports, meaning that a strong dollar, as expected, is harmful to U.S. turkey exports. Finally, increases in production have a positive impact on exports beyond that captured in the trend component.

A main conclusion from the analysis of turkey exports is that both the trend and seasonal components are important in explaining export variations. The trend component is, as expected, stochastic, and effectively captures the changes that have occurred after the end of the cold war. However, the highly significant seasonal component was found to be fixed, a situation that was

not found for broilers and that did not characterize several other turkey variables, including domestic production and consumption. This is surprising because U.S. turkey production no longer has a significant seasonal component and the seasonal consumption component has declined in magnitude. While influencing increased turkey production, rising consumption and exports stem mainly from decreasing real prices of turkey meat due to technological advances. However, it should be noted that exchange rates also play a key role in turkey exports.

Confirmation of Poultry Cycles

Throughout this study, the problem of the variability, as well as the growth, in poultry export changes has been emphasized. This variability is typified in the form of short term cycles and seasonal variations. In this section, a further analysis is made of the nature of these cyclical changes with particular attention given to whether the cycles are driven strictly by external (exogenous) forces or whether such cycles are endemic (endogenous) to the poultry industry itself. This possibility is explored by utilizing advanced characteristics of the STS model to compare a trend plus cycle model with a cyclical trend model. These models are evaluated using monthly export data for specific poultry products: (i) live poultry, (ii) whole young chickens, (iii) chicken pieces, (iv) whole turkey, (v) turkey pieces, (vi) other poultry meat, (vii) poultry livers, and (viii) prepared poultry meats. Data are based on quantities exported rather than monetary values to avoid problems caused by fluctuating exchange rates.

Pre-estimation Diagnostics

The results of a pre-estimation diagnostic, the sample autocorrelation and partial autocorrelation coefficients for the first differences of the twelve series for the entire period (1980:01-1996:12) are reported in Table 5. These variables indicate that the export series do not meet the weak condition for the existence of a cyclical component: positive first order

Table 5. Sample Autocorrelation and Partial Autocorrelation Coefficients of First Differences, 1980:1-1996:12

Lag	Live Poultry	Whole Young Chickens	Chicken Pieces	Whole Turkey	Turkey Pieces	Other Poultry Meat	Poultry Livers	Prepared Poultry Meats
				(i) Autocorrelations				
1	-0.408	-0.307	-0.488	-0.165	-0.495	-0.276	-0.699	-0.502
2	0.067	-0.126	0.059	-0.138	0.095	-0.118	0.367	0.076
3	0.032	0.091	-0.033	0.035	-0.038	-0.071	-0.198	0.179
4	0.026	-0.016	0.020	-0.120	-0.081	-0.034	0.092	-0.319
5	-0.069	-0.085	0.067	-0.097	0.067	-0.042	-0.055	0.190
6	-0.136	0.075	-0.209	-0.071	-0.077	0.024	0.045	-0.172
7	0.259	0.102	0.364	-0.119	0.050	-0.159	-0.097	-0.069
8	-0.195	-0.197	-0.345	-0.063	-0.019	0.201	0.156	0.193
9	-0.062	0.123	0.161	0.094	0.079	0.075	-0.224	-0.205
10	0.212	-0.079	-0.074	-0.071	0.039	0.006	0.247	0.178
11	-0.093	0.057	0.022	0.111	-0.132	-0.111	-0.304	-0.005
12	0.091	-0.004	0.104	0.316	0.078	-0.014	0.262	-0.098
				(ii) Partial Autocorrelations				
1	-0.408	-0.307	-0.488	-0.165	-0.495	-0.276	-0.699	-0.502
2	-0.120	-0.243	-0.236	-0.169	-0.198	-0.210	-0.239	-0.236
3	0.017	-0.037	-0.156	-0.020	-0.110	-0.190	-0.098	0.152
4	0.067	-0.029	-0.083	-0.149	-0.186	-0.170	-0.073	-0.184
5	-0.036	-0.097	0.057	-0.157	-0.097	-0.187	-0.070	-0.080
6	-0.226	0.007	-0.194	-0.183	-0.138	-0.138	-0.017	-0.217

autocorrelation coefficient for the first difference along with higher order coefficients that are not strictly zero. However, the stronger condition for a cycle, the existence of a second order autocorrelation pattern, is met by all of the series.

Model Estimation and Results

The estimation of this type of model requires that two distinct periods be examined, largely due to the excessive instability of the export variations and because other evidence indicates that two periods (1980:01-1987:09 and 1987:10-1996:12) exist. The break points for the two periods are identified in Badillo et al. (1999) by use of endogenous and exogenous break point tests. The maximum likelihood (ML) estimation results for the two sub-periods are reported in Table 6, which includes estimates of the hyperparameters ($\sigma_{level}^2 = \sigma_\eta^2$, $\sigma_{slope}^2 = \sigma_\zeta^2$, $\sigma_{cycle}^2 = \sigma_\kappa^2$, and $\sigma_{irregular}^2 = \sigma_\vartheta^2$): the damping factor, ρ; the cycle frequency, λ_c; and the cycle period, $2\pi/\lambda_c$. Diagnostics for the estimated models are given in Appendix C.

The more general and particularly salient features of the results are discussed below–for more detail see Kouassi, Labys and Colyer (1999). These results are robust for alternative break points between these sub-periods and indicate that the export cycles are endogenous, irrespective of sub-period. The results in Table 6 indicate that a model with *trend-cycle* decomposition is preferred based on goodness-of-fit statistics and post-sample testing for all the poultry series (see Harvey, 1989, 1994). A second significative finding is that the overwhelming majority of the series in both sub-periods are characterized by a deterministic trend ($\sigma_{level}^2 = \sigma_{slope}^2 = 0$) and an additive cyclical component ($\rho > 0$). The damping factor, ρ, results reveal several point estimates greater than or equal to 0.80 in each sub-period, implying that the cyclical components are dramatically undamped but stationary. A 95 percent two-tailed confidence interval for ρ contains 1.0 for six of the eight cycles in each sub-period. The exceptions are for live poultry and prepared poultry meats for sub-period1, and poultry livers and prepared poultry meats for sub-period 2. Moreover, and irrespective of sub-period, the cycles are statistically indistinguishable from constant amplitude cycles, a finding that provides strong evidence for the

Table 6. STS Models for U.S. Poultry Products Series

Parameters	Live Poultry	Whole Young Chicken	Chicken Pieces	Whole Turkey	Turkey Pieces	Other Poultry Meats	Poultry Livers	Prepared Poultry Meats
				Trend Plus Cycle Model [1980:01 - 1987:09]				
δ^2_{level}	0	0	0	0	0	0	0	0
δ^2_{slope}	0	0	0	0	0	0	0	0
δ^2_{cycle}	3.21×10^6	2.23×10^4	0	0	0	9.933×10^7	0	5.253×10^3
$\delta^2_{irregular}$	1.58×10^{10}	1.86×10^6	4.736×10^6	5.192×10^5	1.56×10^{12}		8.817×10^5	
ρ	0.976	1.34×10^{-6}	1	1	0.866	0.989	1	9.234×10^{-8}
λ_c	2.622	0.917	1.046	0.534	0.869	0.881	0.486	0.723
$2\pi/\lambda_c$	2.396	6.850	6.005	11.765	7.224	8.725×10^5	12.915	8.686
				Trend Plus Cycle Model [1987:11 - 1996:12]				
δ^2_{level}	0	0	0	0	0	0	0	0
δ^2_{slope}	0	0	0	0	0	0	0	0
δ^2_{cycle}	6.64×10^8	1.7×10^4	1.768×10^5	0	5.986×10^8	1.032×10^7	3.015×10^8	0
$\delta^2_{irregular}$	8.54×10^{11}	9.82×10^5	1.714×10^7		5.218×10^{12}	1.032×10^7	3.743×10^5	3.396×10^{12}
ρ	4.41×10^{-6}	0.816	4.713×10^{-6}	1	5.103×10^{-7}	0.971	0.904	0.993
λ_c	1.131	2.542	0.525	0.529	1.339	2.495	3.114	0.684
$2\pi/\lambda_c$	5.554	2.471	11.952	3.048×10^{11}	4.689	2.517	2.017	9.183

existence of self-generating, endogenous cycles in the poultry export series. The combined findings of constant amplitude cycles coexisting with a deterministic stochastic trend in both sub-periods strongly supports the hypothesis that cycles are endogenous phenomena with little or no dependence on random shocks.

Simulation Results

Findings with respect to the nature of U.S. poultry export cycle and the relative importance of the cycles found are crucial for a more complete understanding of poultry trade. Thus, to further investigate the cyclical aspects of poultry trade, Monte Carlo simulations were made utilizing the eight time series of disaggregated poultry exports. For this purpose, the approach developed by Goldstein (1997) was used. Each estimated cycle, ψ_t, in each of the two time periods (1980:01-1987:09 and 1987:11-1996:12) is decomposed into three components: a pure endogenous cycle, EC; a pure stochastic cycle, SC; and a mixed endogenous-stochastic cycle, MC. This decomposition is carried out where the independent evolution of the LHS (left hand side) of the equation determines the endogenous cycle and the independent evolution of the RHS (right hand side) generates the stochastic cycles (for details, see Kouassi, Labys and Colyer 1999, equation 9). The mixed cycle is calculated as a residual where ψ_t - *ec* - *sc* represents the effects of past stochastic shocks.

To assess the relative importance of each component, ψ_t and its three components are simulated by performing (i)1,000, (ii) 5,000 and (iii)10,000 and (iv) 20,000 simulation replications.[2] Then the average correlation coefficients between ψ_t and EC, SC, (EC + MC) and (SC + MC) are calculated. These correlation coefficients are reported in Table 7 for the first

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[2] In each trial, the initial conditions for the recursion in equation are taken from the first two values of ψ_t generated by the smoothing algorithm when applied to the estimated models in Table 6. The initial values for κ and κ^* are assumed to be zero. κ_t and κ_t^* are generated as NID (0, $\hat{\sigma}^2_{cycle}$). $\hat{\lambda}_c$ and $\hat{\rho}$ are used for λc and ρ, except for the case where ρ is set to one.

sub-period and Table 8 for the second subperiod, with calculations made for two values of ρ: (i) $\rho = \hat{\rho}$ (from Table 6) and (ii) $\rho = 1$.

The treatment of the mixed cycle component, MC, is determinant for the interpretation of the results in Tables 7 and 8. Endogenous and exogenous cycle theorists disagree and, respectively, consider MC as an endogenous or stochastic element. While the results reported in Tables 7 and 8 are consistent with both interpretations, this report focuses on the endogenous approach. In particular, it is found that a stochastic shock, irrespective of the complexity of its dynamic structure, such as the RHS of equation (9), has no subsequent effect of its own unless it is absorbed into the systematic, i.e., endogenous, propagation mechanism. At that point, it becomes part of the endogenous cycle and loses its independent existence, thus, supporting the findings of the preceding analysis which indicates that the cycles of the export series are endogenous.

Conclusions

Exports of broiler and turkey meats have become increasingly important to U.S. producers and processors as they now account for substantial portions of the outputs of those products, around 17 percent for broilers and 10 percent for turkeys. Due to increased efficiency in both feed and labor used for production as well as in the processing and marketing, poultry meats have become relatively inexpensive compared to beef, pork and other meats. Consequently, pre capita consumption of broiler and turkey meats have risen substantially in most countries; in the U.S. chicken now exceeds beef consumption. While relatively lower prices account for much of the increase in consumption, poultry, especially the white meat, is also perceived as being healthier than the red meats. The preference for white meat cuts has led to even lower prices for the dark cuts, an important factor in the increases in exports. Thus, the

increase in poultry exports has been primarily in pieces rather than whole birds with the largest share of the pieces being the dark meats, primarily leg quarters.

The analyses of U.S. poultry meat exports indicate there are strong trend components in the exports of both chicken and turkey. A seasonal component is still important in turkey but not chicken exports; turkey exports appear to be related to demand during the Christmas holidays. For both products, real price is a major explanatory factor as are exchange rates that affect the importers in terms of their total domestic costs. Prices of competitor products affect exports but are relatively minor, especially for turkey exports. Barriers to trade also affect exports to countries that impose restrictions of various types.

Table 7. Simulated Correlation Coefficients for Cycle, Endogenous & Stochastic Components [Sub-Period 1]

	Average Correlation Coefficient									
	$\rho = \hat{\rho}$					$\rho = 1$				
Variable	Ψ, EC	Ψ, SC	Ψ, MC	Ψ, (EC+MC)	Ψ, (SC+MC)	Ψ, EC	Ψ, SC	Ψ, MC	Ψ, (EC+MC)	Ψ, (SC+MC)
1,000 Replications										
Live Poultry	0.1372	0.1013	0.9049	0.9149	0.9907	0.5991	-0.0045	-0.5991	0.9871	-0.5991
Whole Chickens	0.2558	0.9975	0.0616	0.2558	0.9975	0.1022	0.0144	1.00	1.00	1.00
Chicken Pieces	0.2236	0.1760	0.9556	0.9612	0.9955	0.2268	0.1760	0.9552	0.9612	0.9951
Whole Turkey	0.1475	0.0609	0.9574	0.9690	0.9888	0.0643	0.0609	-0.0643	0.9690	-0.0643
Turkey Pieces	0.2467	0.4565	0.7536	0.7629	0.9976	0.2226	-0.0057	0.9999	1.00	0.9999
Other Poultry Meat	0.2113	0.1870	0.9407	0.9463	0.9961	0.3754	-0.0114	0.9995	1.00	0.9995
Poultry Livers	0.1221	0.0508	0.9547	0.9684	0.9863	-0.0239	0.0508	0.0239	0.9684	0.0239
Prepared Meats	0.2588	0.9975	0.0616	0.2558	0.9975	0.2174	0.0076	1.00	1.00	1.00
5,000 Replications										
Live Poultry	0.1302	0.1008	0.9038	0.9139	0.9906	0.6198	-0.0029	-0.6178	0.9868	-0.6198
Whole Chickens	0.2556	0.9975	0.0632	0.2556	0.9975	0.1022	0.0118	1.00	1.00	1.00
Chicken Pieces	0.2367	0.1772	0.9547	0.9605	0.9954	0.2397	0.1772	0.9543	0.9605	0.9950
Whole Turkey	0.1421	0.0633	0.9567	0.9685	0.9886	0.0539	0.0633	-0.0539	0.9685	-0.0539
Turkey Pieces	0.2493	0.4565	0.7531	0.7625	0.9976	0.2203	-0.0056	0.9997	1.00	0.9997
Other Poultry Meat	0.2257	0.1867	0.9399	0.9455	0.9960	0.3812	-0.0077	0.9997	1.00	0.9997
Poultry Livers	0.1272	0.0517	0.9572	0.9702	0.9871	-0.0254	0.0517	0.0254	0.9702	0.0254
Prepared Meats	0.2556	0.9975	0.0632	0.2556	0.9975	0.2174	0.0046	1.00	1.00	1.00
10,000 Replications										
Live Poultry	0.1267	0.1011	0.9038	0.9137	0.9906	0.6426	-0.0033	-0.6426	0.9887	-0.6426
Whole Chickens	0.2557	0.9975	0.0628	0.2557	0.9975	0.1022	0.0124	1.00	1.00	1.00
Chicken Pieces	0.2440	0.1767	0.9549	0.9607	0.9955	0.2472	0.1767	0.9545	0.9607	0.9951
Whole Turkey	0.1432	0.0630	0.9568	0.9686	0.9887	0.0548	0.0630	-0.0548	0.9686	-0.0548
Turkey Pieces	0.2496	0.4562	0.7524	0.7618	0.9975	0.2229	-0.0062	0.9997	1.00	0.9997
Other Poultry Meat	0.2201	0.1859	0.9399	0.9455	0.9960	0.3807	-0.0091	0.9995	1.00	0.9995
Poultry Livers	0.1314	0.0521	0.9572	0.9702	0.9872	-0.0242	0.0521	0.0242	0.9702	0.0242
Prepared Meats	0.2551	0.9975	0.0628	0.2557	0.9975	0.2174	0.0055	1.00	1.00	1.00
20.000 Replications										
Live Poultry	0.1270	0.1012	0.9038	0.9137	0.9906	0.6451	-0.0030	-0.6451	0.9888	-0.6451
Whole Chickens	0.2556	0.9975	0.0624	0.2556	0.9975	0.1022	0.0126	1.00	1.00	1.00
Chicken Pieces	0.2477	0.1770	0.9544	0.9605	0.9954	0.2477	0.1770	0.9548	0.9605	0.9954
Whole Turkey	0.1411	0.0624	0.9570	0.9686	0.9887	0.0556	0.0624	-0.0556	0.9686	-0.0556
Turkey Pieces	0.2497	0.4559	0.7525	0.7619	0.9975	0.2236	-0.0059	0.9998	1.00	0.9998
Other Poultry Meat	0.2205	0.1853	0.9400	0.9456	0.9960	0.3795	-0.0093	0.9995	1.00	0.9995
Poultry Livers	0.1240	0.0520	0.9570	0.9700	0.9871	-0.0261	0.0520	0.0261	0.9700	0.0261
Prepared Meats	0.2556	0.9975	0.0624	0.2556	0.9975	0.2174	0.0056	1.00	1.00	1.00

Notes: All simulations were conducted on an IBM Pentium 266 Mhz.Computer

Table 8. Simulated Correlation Coefficients for Cycle, Endogenous & Stochastic Components [Sub-Period 2]

	Average Correlation Coefficient									
	$\rho = \hat{\rho}$					$\rho = 1$				
Variable	Ψ, EC	Ψ, SC	Ψ, MC	Ψ, (EC+MC)	Ψ, (SC+MC)	Ψ, EC	Ψ, SC	Ψ, MC	Ψ, (EC+MC)	Ψ, (SC+MC)
1,000 Replications										
Live Poultry	0.2558	0.9975	0.0616	0.2558	0.9975	0.1833	0.5549	0.7847	0.7931	0.9978
Whole Chickens	0.1464	0.3513	0.6692	0.6795	0.9948	0.2774	-0.0055	-0.2774	0.9931	-0.2774
Chicken Pieces	0.2558	0.9975	0.0616	0.2558	0.9975	0.8306	0.0042	1.00	1.00	1.00
Whole Turkey	0.1448	0.0594	0.9571	0.9690	0.9885	0.0342	0.0594	-0.0342	0.9690	-0.0342
Turkey Pieces	0.2558	0.9975	0.0616	0.2558	0.9975	0.2164	0.7557	0.5816	0.5966	0.9988
Other Poultry Meat	0.1341	0.1494	0.8950	0.9023	0.9940	-0.1312	-0.0027	0.1312	0.9546	0.1312
Poultry Livers	0.5132	0.0647	0.7140	0.8600	0.8600	0.9864	-0.0023	-0.9864	1.00	-0.9864
Prepared Meats	0.1686	0.1150	0.9491	0.9562	0.9939	-0.4857	0.0014	1.00	1.00	1.00
5,000 Replications										
Live Poultry	0.2556	0.9975	0.0632	0.2556	0.9975	0.2556	0.9975	0.7865	0.7948	0.9978
Whole Chickens	0.1462	0.3513	0.6683	0.6785	0.9948	0.2886	-0.0013	-0.2886	0.9959	-0.2886
Chicken Pieces	0.2556	0.9975	0.0632	0.2556	0.9975	0.8239	0.0013	1.00	1.00	1.00
Whole Turkey	0.1430	0.0622	0.9567	0.9687	0.9884	0.0251	0.0622	-0.0251	0.9687	-0.0251
Turkey Pieces	0.2556	0.9975	0.0632	0.2556	0.9975	0.2165	0.7551	0.5838	0.5987	0.9988
Other Poultry Meat	0.1304	0.1490	0.8952	0.9024	0.9940	-0.1412	0.0006	0.1412	0.9502	0.1412
Poultry Livers	0.5154	0.0655	0.7118	0.8583	0.8672	0.9864	-0.0029	-0.9864	1.00	-0.9864
Prepared Meats	0.1918	0.1161	0.9487	0.9561	0.9938	-0.4880	0.0006	1.00	1.00	1.00
10,000 Replications										
Live Poultry	0.2557	0.9975	0.0628	0.2557	0.9975	0.1839	0.5529	0.7864	0.7948	0.9978
Whole Chickens	0.1449	0.3513	0.6689	0.6791	0.9948	0.3057	-0.0012	-0.3057	0.9953	-0.3057
Chicken Pieces	0.2557	0.9975	0.0628	0.2557	0.9975	0.8306	0.0024	1.00	1.00	1.00
Whole Turkey	0.1441	0.0618	0.9568	0.9688	0.9885	0.0258	0.0618	-0.0258	0.9688	-0.0258
Turkey Pieces	0.2557	0.9975	0.0628	0.2557	0.9975	0.2171	0.7544	0.5829	0.5979	0.9988
Other Poultry Meat	0.1298	0.1493	0.8956	0.9026	0.9940	-0.1299	0.0017	0.1299	0.9480	.1299
Poultry Livers	0.5110	0.0656	0.7128	0.8581	0.8678	0.9864	-0.0036	-0.9864	1.00	-0.9864
Prepared Meats	0.1843	0.1157	0.9485	0.9559	0.9937	-0.4820	0.0024	1.00	1.00	1.00
20,000 Replications										
Live Poultry	0.2556	0.9975	0.0624	0.2556	0.9975	0.1837	0.5526	0.7865	0.7950	0.9978
Whole Chickens	0.1447	0.3511	0.6691	0.6792	0.9948	0.3115	-0.0014	-0.3115	0.9948	-0.3115
Chicken Pieces	0.2556	0.9975	0.0624	0.2556	0.9975	0.8306	0.0030	1.00	1.00	1.00
Whole Turkey	0.1417	0.0613	0.9569	0.9687	0.9885	0.0264	0.0613	-0.0264	0.9687	-0.0264
Turkey Pieces	0.2556	0.9975	0.0624	0.2556	0.9975	0.2169	0.7542	0.5832	0.5982	0.9988
Other Poultry Meat	0.1262	0.1433	0.8950	0.9021	0.9939	-0.1231	0.0006	0.1231	0.9496	0.1231
Poultry Livers	0.5135	0.0655	0.7131	0.8585	0.8680	0.9864	-0.0033	-0.9864	1.00	-0.9864
Prepared Meats	0.1850	0.1161	0.9481	0.9560	0.9938	-0.4791	0.0030	1.00	1.00	1.00

Notes: All simulations were conducted on an IBM Pentium 266 Mhz.

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APPENDIX A: STRUCTURAL TIME SERIES MODELS

The modeling approach we employ combine economic market and time series variables, emphasizing the underlying trend, seasonal, cycle and stochastic components. This method is well known, principally due to the efforts of Harvey(1989, 1994). The advantages of this approach are that it includes a less restrictive specification of cycles and effectively considers relevant stochastic and deterministic trend and cycle models as nested alternatives or mixed models which can be decomposed. Let y_t be the time series to be modeled:

$$y_t = \mu_t + \psi_t + \epsilon_t \qquad \text{(A1)}$$

where μ_t is the trend component, ψ_t is the cyclical component, ϵ_t is the irregular component, and t ranges between 1 and T. Harvey suggests that the empirical characteristics of each component can be determined by investigating two models, the trend plus cycle model and cyclical trend model.

Trend plus Cycle Model

The specification of this model consists of trend, cycle and irregular component combined in an additive form, i.e.

$$y_t = \mu_t + \psi_t + \varepsilon_t \,, \quad t = 1,\ldots,T \qquad \text{(A2)}$$

where μ_t is the trend component, ψ_t is the cyclical component, and ε_t is the irregular component. The trend component is generated as

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \,, \; t = 1,\ldots,T \qquad \text{(A3)}$$

and

$$\beta_t = \beta_{t-1} + \zeta_t \text{ , } t = 1,....,T \tag{A4}$$

The cycle component ψ_t is described in Harvey's methodology as a function of time with frequency λ_c (measured in radians). More formally, the cycle component is described as a mixture of sine and cosine waves. When time variation is included, the stochastic cycle can be modeled recursively using a rotation matrix:

$$\begin{bmatrix} \psi_t \\ \psi_t^* \end{bmatrix} = \rho \begin{bmatrix} \cos\lambda_c & \sin\lambda_c \\ -\sin\lambda_c & \cos\lambda_c \end{bmatrix} \begin{bmatrix} \psi_{t-1} \\ \psi_{t-1}^* \end{bmatrix} + \begin{bmatrix} \kappa_t \\ \kappa_t^* \end{bmatrix} \tag{A5}$$

where ρ is the damping factor, $0 \leq \rho \leq 1$, $0 \leq \lambda_c \leq \pi$, and κ_t and κ_t^* are two white-noise disturbances.

Since (ψ_t, ψ_t^*) is a VAR of order one, the reduced solved form of (5) is given by:

$$\begin{bmatrix} \psi_t \\ \psi_t^* \end{bmatrix} = \begin{bmatrix} 1 - \rho \cos\lambda_c.L & -\rho \sin\lambda_c.L \\ \rho \sin\lambda_c.L & 1 - \rho \cos\lambda_c.L \end{bmatrix}^{-1} \begin{bmatrix} \kappa_t \\ \kappa_t^* \end{bmatrix} \tag{A6}$$

where L is the lag operator. Let the matrix on the right hand of (6) be represented by A as follows:

$$A = \begin{bmatrix} 1 - \rho \cos\lambda_c.L & -\rho \sin\lambda_c.L \\ \rho \sin\lambda_c.L & 1 - \rho \cos\lambda_c.L \end{bmatrix} \tag{A7}$$

Using the inverse of A, we can solve for a more concise statement of the cyclical component; which can be substituted into the expression for y_t,

$$y_t = \mu_t + \frac{(1 - \rho\cos\lambda_c.L)\ \kappa_t + (\rho\sin\lambda_c.L)\ \kappa_t^*}{(1 - 2\rho\cos\lambda_c.L + \rho^2 L^2)} + \varepsilon_t \tag{A8}$$

In this structural model, ε_t is the white-noise disturbance term with mean zero and variance, σ_ε^2.

The stationarity operator for this structural time series model (e.g., see Harvey 1989) is

$$\Delta^2 = (1 - B)\ (1 - B) \tag{A9}$$

while the reduced form is an ARIMA (2, 2, 4); (e.g., see Harvey 1989 and 1994, and Harvey and Peters, 1990).

Cyclical Trend Model

A non-nested alternative to the trend plus cycle specification is the cyclical trend (level) specification. In the cyclical trend model the cycle is actually incorporated within the trend. The series to be modeled now supports a trend component, μ_t, whose behavior is cyclical,

$$y_t = \mu_t + \varepsilon_t\ , \qquad t = 1,....,T \tag{A10}$$

$$\beta_t = \beta_{t-1} + \zeta_t\ , \quad t = 1,....,T \tag{A11}$$

Equation (10) is as defined previously, while equation (11) is modified to be

$$\mu_t = \mu_{t-1} + \psi_{t-1} + \beta_{t-1} + \eta_t\ \ , \ t = 1,....,T \tag{A12}$$

Substituting equations (11), (12) and (5) into equation (10) gives

$$y_t = \frac{\mu_t}{\Delta} + \frac{(1 - \rho\cos\lambda_c.L)\ \kappa_{t-1} + (\rho\sin\lambda_c.L)\ \kappa^*_{t-1}}{\Delta\ (1 - 2\rho\cos\lambda_c.L + \rho^2 L^2)} + \frac{\zeta_{t-1}}{\Delta^2} + \varepsilon_t \tag{A13}$$

In the two structural models, ε_t is the white-noise disturbance term with mean zero and variance, σ_ε^2.

The stationarity operator for this structural time series model (e.g., see Harvey 1989) is also

$$\Delta^2 = (1 - B)\ (1 - B) \tag{A14}$$

while the reduce form is an ARIMA (2, 2, 4); (e.g., see Harvey 1989 and 1994, and Harvey and Peters, 1990).

Maximum Likelihood Estimation

Among the methods that can be used to estimate the parameters of STS models (e.g. see Harvey 1989; and Harvey and Peters, 1990), the maximum likelihood (ML) estimation procedure in the time domain (e.g., see Harvey, 1989 and Harvey and Peters, 1990) has often been considered. In this case, a state space representation has first to be considered.

State Space Representation

Regarding the trend plus cycle model, the state space formulation is straightforward. The measurement equation is

$$y_t = [1\ \ 0\ \ 1\ \ 0]\ x_t + \varepsilon_t\ , \quad t = 1,\dots,T \tag{A15}$$

while the transition equation is

$$x_t = \begin{bmatrix} \mu_t \\ \beta_t \\ \hline \psi_t \\ \psi_t^* \end{bmatrix} = \left[\begin{array}{cc|cc} 1 & 1 & & \\ 0 & 1 & \multicolumn{2}{c}{\mathbf{0}} \\ \hline \multicolumn{2}{c|}{\mathbf{0}} & \rho\cos\lambda_c & \rho\sin\lambda_c \\ & & -\rho\sin\lambda_c & \rho\cos\lambda_c \end{array}\right] \begin{bmatrix} \mu_{t-1} \\ \beta_{t-1} \\ \hline \psi_{t-1} \\ \psi_{t-1}^* \end{bmatrix} + \begin{bmatrix} \eta_t \\ \zeta_t \\ \hline \kappa_t \\ \kappa_t^* \end{bmatrix} \tag{A16}$$

The covariance matrix of the vector of disturbance in (16) is a diagonal matrix with diagonal elements (σ_η^2, σ_ζ^2, σ_κ^2, $\sigma_{\kappa^*}^2$). The model is observable unless ρ is zero or λ_c is zero or π. However, it is always detectable. The condition that σ_κ^2 as well as $\sigma_{\kappa^*}^2$, be strictly positive is necessary for controllability and stabilisability.

As to the cyclical trend model[3], the state space formulation is as follows. The measurement equation is

$$y_t = [1\ 0\ 0\ 0]\ x_t + \varepsilon_t\ , \quad t = 1,\ldots,T \tag{A17}$$

while the transition equation is

$$x_t = \begin{bmatrix} \mu_t \\ \beta_t \\ \hline \psi_t \\ \psi_t^* \end{bmatrix} = \left[\begin{array}{cc|cc} 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ \hline 0 & 0 & \rho\cos\lambda_c & \rho\sin\lambda_c \\ 0 & 0 & -\rho\sin\lambda_c & \rho\cos\lambda_c \end{array}\right] \begin{bmatrix} \mu_{t-1} \\ \beta_{t-1} \\ \hline \psi_{t-1} \\ \psi_{t-1}^* \end{bmatrix} + \begin{bmatrix} \eta_t \\ \zeta_t \\ \hline \kappa_t \\ \kappa_t^* \end{bmatrix} \tag{A18}$$

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[3]We are grateful to Professor Andrew C. Harvey (University of Cambridge, UK) for providing the SSFPack 2.2 program. All estimations based on the cyclical trend model were conducted using the SSFPack 2.2 programs in the Ox environment.

The covariance matrix of the vector of disturbance in (18) is a diagonal matrix with diagonal elements (σ_η^2, σ_ζ^2, σ_κ^2, $\sigma_{\kappa*}^2$).The model is observable unless ρ is zero or λ_c is zero or π. However, it is always detectable. The condition that σ_κ^2 as well as $\sigma_{\kappa*}^2$, be strictly positive is necessary for controllability and stabilisability.

Statistical treatment of the previous STS models requires that hyper-parameters (σ_η^2, σ_ζ^2, σ_ω^2, σ_κ^2, ρ, λ_c, σ_ε^2) which govern the evolution of the unobserved components (state variables), be estimated. The Kalman filter is used to decompose the likelihood function into one-step ahead prediction errors, thus allowing for maximum likelihood (ML) estimates of the hyper-parameters to be generated. After the estimation of the parameters, the Kalman filter recursion equations are used again to generate optimal forecasts and optimal estimates of the entire state (trend, cycle) trajectories via a smoothing algorithm.

APPENDIX B. DEFINITIONS OF VARIABLES USED IN THE BROILER MODEL

Endogenous Variables	
QBP	Broiler production (million pounds)
QBD	Broilers consumed, ready to cook (million pounds)
QBID	Broiler inventories demand (1,000 lbs)
QBX	Broiler exports (1,000 lbs)
WPB	Wholesale price of broilers (dollars per100 pounds)
BID_i	Per capita imports of U.S. broilers by country i (pounds)
CRBP	Retail price of beef (dollars per100 pounds)
RPP	Retail price of pork (dollars per100 pounds)
RPT	Retail price of turkey (dollars per100 pounds)
PBF	Real price of broiler feed (cents per pound)
Exogenous Variables: One quarter lagged dependent variables	
HATCH	Hatch of broiler in commercial hatcheries (1,000 chicks)
PCI	Per capita disposable personal income (current dollars per person)
$RFOPBr_i$	Real FOB price of broilers imported by country i (1987 dollars per metric ton)
$RFOBIP_i$	Real FOB price of beef imported by country i (1987 dollars per100 pounds)
$RFOPOIP_i$	Real FOB price of pork imported by country i (1987 dollars per100 pounds)
YE_i	Real per capita gross domestic product (GDP) of the importing country in the currency of the importer (base year 1985)
$PCQBP_i$	Per capita production of broilers in the ith importing country (Kg per capita)
RSD_i	Real exchange rate between currency of the importing country and one U.S. dollar (base year 1987) (U.S. dollars)
μ_t	Stochastic trend component
γ_t	Stochastic seasonal component
ψ_t	Stochastic cyclical component
ϵ_t	disturbance term

APPENDIX C
DIAGNOSTIC TESTS FOR POULTRY PARTS MODELS

Table C1 presents goodness of fit statistics: the prediction error variance for one step-ahead predictions, PEV; the Box-Ljung test for serial correlation of the residuals, Q (lag length); the Jarque-Bera test for normality of the residuals, N; the standard split sample test for heteroscedasticity, H; and the percentage improvement in fit over a random walk plus drift model, R_D^2. Table 8 reports post-sample testing results (Chow F test, and CUSUM(t) test to assess whether the mean of a time series has changed over time). Furthermore, a series of nonstandard tests are used for some parameters of the STS model where standard tests are not valid; these are valid as long as all of the other regularity conditions are met. Thus, the most powerful invariant test (MPI) is used to test for a deterministic trend ($\sigma_\zeta^2 = \sigma_\eta^2 = 0$), the likelihood ratio test (LR) is used to test that $\sigma_\zeta^2 = 0$, and a modified Lagrange multiplier (LM) test is employed to test that $\rho = 0$ and $\rho = 1$. The results to determine if the models are mis-specified are based on tests for normality, heteroscedasticity, and serial correlation. The normality statistic is under the null is a $\chi^2(2)$ distribution. The statistic for heteroscedasticity is under the null of homoscedasticity F(9, 9) distributed, and the Ljung-Box statistic is under the null hypothesis of white noise a $\chi^2(12)$ distribution. The prediction error variance for one step-ahead predictions is globally satisfactory in any of the sub-periods. Normality is acceptable except for other poultry meat, turkey pieces and prepared poultry meats. The test for heteroscedasticity is also accepted, except for poultry livers. Moreover, additional investigations indicate that the trend plus cycle model with structural breaks used here, is superior in all cases to the alternative cyclical trend specification.

The R_D^2 statistics, which report the percentage improvement in fit over the random walk with drift model which is a special case of the DS formulation and the basic representation of the dominant stochastic cycle theory, range from 0.606 to 0.710 for the first sub-period and from 0.598 to 0.694 for sub-period 2 and, thus, provide further evidence of the importance of the undamped (endogenous) cyclical component found in the majority of models.

To further evaluate the adequacy of the estimated models, their post-sample predictive performance is assessed. In each case, the formal post-sample predictive test is based on the final value of the CUSUM test by dividing it by the square-root of the number of post-sample observations. An alternative test considered is the Chow F test (e.g., see Harvey, 1989). Under the hypothesis that the model is correctly specified, the Chow statistic is F(9, 81) distributed for sub-period 1 and F(11, 97) for sub-period 2, while the CUSUM statistic has a t(81) distribution in both the first and second sub-periods. Except in the series for whole young chickens and chicken pieces for sub-period 1 and whole young chickens, chicken pieces, turkey pieces and prepared poultry meats for sub-period 2, post-sample results indicate rather better predictions than in the sample period and, thus, provides additional evidence of the appropriateness of the STS approach in modeling the U.S. poultry cycles.

Table C1. Diagnostics of the Poultry STS Model

Poultry Series:	Live Poultry	Whole Young Chickens	Chicken Pieces	Whole Turkey	Turkey Pieces	Other Poultry Meats	Poultry Livers	Prepared Poultry Meats
Trend Plus Cycle Model (1980.0–1987.09)								
PEV	2.49×10^{-2}	3.42×10^{-2}	2.22×10^{-2}	2.67×10^{-2}	1.52×10^{-2}	7.55×10^{-2}	7.67×10^{-2}	2.69×10^{-2}
R_D^2	0.615	0.613	0.652	0.622	0.660	0.606	0.710	0.670
H(30)	2.056	0.387	0.936	0.227	0.793	0.193	70.378a	1.979
Q(11, 6)	17.47	19.13	29.25	27.18	17.96	17.96	98.72a	29.99
N	2631[a]	50.47[a]	0.420	0.106	211.9[a]	211.9[a]	16.84	149.3[a]
Trend Plus Cycle Model (1987.10–1995.12)								
PEV	8.46×10^{-2}	9.50×10^{-2}	2.90×10^{-2}	3.02×10^{-2}	4.96×10^{-2}	9.05×10^{-2}	1.40×10^{-2}	3.35×10^{-2}
R_D^2	0.647	0.608	0.671	0.598	0.666	0.623	0.694	0.656
H(30)	0.713	3.780	5.275	6.581	10.47	0.098	1.653	35.72[a]
Q(11, 6)	4.312[a]	33.93[a]	73.52[a]	13.14	35.10[a]	23.87	68.41[a]	71.98[a]
N	4.522	74.58[a]	12.63	319.9[a]	13.39	344.6[a]	3.455	69.84[a]

Notes: a, b, and c indicate statistical significance at the 1percent level; PEV=Prediction Error Variance

Table C2. Post-Sample Testing

Poultry Export Series:	Live Poultry	Whole Young Chickens	Chicken Pieces	Whole Turkey	Turkey Pieces	Other Poultry Meats	Poultry Livers	Prepared Poultry Meats
Trend Plus Cycle Model [1980:01 – 1987:09]								
Chow-F (9, 81)	0.680	3.096[b]	1.874[c]	0.220	0.272	0.153	0.155	0.680
CUSUM-t (81)	-0.125	-0.160	0.714	0.130	-0.010	-0.082	0.067	0.087
Trend Plus Cycle Model [1987:11 – 1996:12]								
Chow-F (11, 97)	0.448	12.290[a]	5.031[b]	0.926	3.925[b]	0.293	0.007	7.853[a]
CUSUM-t (97)	0.830	1.076	0.436	0.282	0.633	-0.689	0.230	-0.298

Note: a, b, and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

APPENDIX D. POULTRY DATA

Table D1. Broilers: Production, Price and Income, 1960-98

Year	Production (1,000) Number	Pounds	Price: ¢/lb	Value $1,000
1960	1,794,933	6,017,217	16.9	1,014,084
1961	1,990,906	6,831,932	13.9	947,433
1962	2,023,373	6,907,076	15.2	1,048,826
1963	2,102,023	7,276,008	14.6	1,062,904
1964	2,161,172	7,521,269	14.2	1,070,124
1965	2,333,633	8,111,426	15.0	1,217,383
1966	2,570,516	8,988,508	15.3	1,371,006
1967	2,591,850	9,183,426	13.3	1,222,641
1968	2,619,855	9,326,341	14.2	1,325,665
1969	2,788,732	10,047,769	15.2	1,531,404
1970	2,986,769	10,818,916	13.6	1,474,710
1971	2,945,348	10,817,657	13.8	1,487,077
1972	3,074,921	11,480,101	14.1	1,622,638
1973	3,008,667	11,219,885	24.0	2,690,362
1974	2,992,820	11,320,396	21.5	2,436,224
1975	2,950,099	11,096,015	26.3	2,915,017
1976	3,273,556	12,481,136	23.6	2,945,058
1977	3,393,897	12,961,942	23.6	3,059,497
1978	3,613,647	13,999,702	26.3	3,675,628
1979	3,951,297	15,521,728	26.0	4,031,945
1980	3,963,211	15,538,573	27.7	4,302,818
1981	4,147,521	16,519,568	28.4	4,699,379
1982	4,148,970	16,759,860	26.9	4,502,214
1983	4,183,660	17,037,998	28.6	4,872,707
1984	4,283,020	17,861,023	33.7	6,020,066
1985	4,469,578	18,809,938	30.1	5,668,272
1986	4,648,520	19,661,110	34.5	6,784,088
1987	5,003,560	21,523,356	28.7	6,177,127
1989	5,516,521	23,978,816	36.6	8,777,915
1990	5,864,150	25,630,960	32.6	8,365,704
1991	6,137,150	27,202,862	30.8	8,383,046
1992	6,402,490	28,828,872	31.8	9,174,136
1993	6,694,310	30,617,600	34.0	10,416,962
1994	7,017,540	32,528,500	35.0	11,371,723
1995	7,325,670	34,222,000	34.4	11,762,222
1996	7,596,760	34,479,100	38.1	13,903,479
1997	7,764,200	37,540,750	37.7	14,158,926
1998	7,934,280	38,553,600	39.3	15,144,551

Table D2. Turkey: Production, Price and Income, 1960-98

Year	Production		Price	Gross income
	Number	1,000 lbs.	¢/lb	$1,000
1960	84,458	1,488,649	25.4	370,925
1961	107,749	1,871,494	18.9	355,826
1962	92,088	1,626,049	21.6	351,531
1963	94,063	1,686,355	22.3	377,313
1964	101,105	1,826,035	21.0	383,405
1965	105,914	1,915,331	22.2	421,295
1966	116,538	2,123,484	23.1	485,750
1967	126,577	2,343,339	19.5	459,581
1968	106,709	2,014,589	20.5	416,738
1969	106,736	2,029,315	22.4	454,115
1970	116,139	2,197,916	22.6	497,815
1971	119,657	2,255,614	22.1	499,576
1972	128,664	2,423,618	22.2	536,945
1973	132,231	2,451,848	38.2	935,882
1974	131,909	2,437,121	28.0	683,164
1975	124,165	2,276,504	34.8	793,271
1976	140,021	2,606,265	31.7	825,095
1977	136,390	2,562,825	35.5	910,396
1978	138,939	2,654,788	43.6	1,157,200
1979	156,457	2,957,612	41.1	1,214,357
1980	165,243	3,076,858	41.3	1,271,637
1981	170,875	3,264,463	38.2	1,247,803
1982	165,464	3,175,060	39.5	1,254,700
1983	170,723	3,335,519	38.0	1,269,051
1984	171,296	3,384,393	48.9	1,654,862
1985	185,427	3,703,994	49.1	1,819,526
1986	207,232	4,147,168	47.0	1,948,437
1987	240,438	4,894,858	34.8	1,703,137
1988	242,421	5,059,056	38.6	1,951,351
1989	261,394	5,467,629	40.9	2,235,145
1990	282,445	6,043,155	39.6	2,393,375
1991	284,910	6,114,620	38.5	2,352,986
1992	289,880	6,355,293	37.7	2,396,364
1993	287,650	6,432,577	39.0	2,509,127
1994	286,605	6,540,827	40.4	2,643,706
1995	292,626	6,837,054	41.6	2,845,525
1996	302,713	7,222,834	43.3	3,124,596
1997	301,251	7,225,049	39.9	2,884,377
1998	283,503	7,002,768	38	2,661,706

Table D3. World Meat and Poultry Production (metric tons)

Year	World	USA	Developed	Developing	EC(15)	Brazil	DEV-US
All Meat							
1980	136,393,600	24,455,200	89,660,450	46,733,120	29,264,480	5,316,689	65,205,250
1981	138,951,000	24,883,150	89,989,080	48,961,930	29,516,540	5,585,967	65,105,930
1982	140,158,500	24,222,120	89,554,320	50,604,210	29,377,950	5,626,493	65,332,200
1983	144,766,500	25,151,150	92,401,330	52,365,200	29,914,470	5,813,344	67,250,180
1984	148,949,500	25,417,450	94,154,540	54,794,910	30,660,970	5,676,550	68,737,090
1985	153,990,600	25,834,360	95,690,840	58,299,780	30,979,370	5,898,738	69,856,480
1986	159,455,800	26,283,500	97,688,020	61,767,760	31,281,700	6,197,736	71,404,520
1987	164,663,800	26,844,300	100,528,300	64,135,560	32,074,070	6,848,814	73,684,000
1988	170,862,400	27,808,250	102,754,000	68,108,450	32,314,270	7,266,223	74,945,750
1989	173,597,600	28,289,330	102,936,200	70,661,380	31,930,070	7,510,809	74,646,870
1990	179,098,500	28,638,770	104,582,100	74,516,470	32,982,480	7,709,088	75,943,330
1991	183,079,600	29,553,400	103,782,800	79,296,840	33,293,190	8,460,203	74,229,400
1992	186,401,600	30,861,320	102,515,200	83,886,460	33,297,470	8,712,318	71,653,880
1993	191,067,100	31,173,980	100,844,100	90,223,070	33,636,180	9,187,891	69,670,120
1994	197,048,700	32,836,600	100,740,200	96,308,490	33,757,270	9,424,857	67,903,600
1995	202,702,400	33,863,450	100,819,600	101,882,800	34,146,960	10,090,750	66,956,150
1996	204,882,000	34,427,460	101,186,000	103,696,000	34,754,440	10,787,730	66,758,540
1997	211,788,800	34,889,000	100,553,600	111,235,200	34,647,290	11,422,830	65,664,600
1998	216,200,700	35,756,000	102,104,500	114,096,200	35,576,280	11,687,830	66,348,500
Chicken Meat							
1980	22,954,790	5,379,000	15,781,720	7,173,073	4,433,753	1,370,000	10,402,720
1981	24,372,030	5,715,000	16,585,550	7,786,486	4,707,413	1,491,000	10,870,550
1982	25,193,610	5,764,000	16,848,130	8,345,478	4,852,044	1,596,000	11,084,130
1983	25,755,950	5,884,000	17,062,050	8,693,904	4,653,998	1,580,000	11,178,050
1984	26,292,570	6,153,000	17,539,970	8,752,598	4,589,042	1,360,000	11,386,970
1985	27,556,330	6,407,000	18,193,880	9,362,456	4,661,125	1,490,000	11,786,880
1986	29,341,600	6,731,000	18,938,110	10,403,490	4,737,953	1,620,000	12,207,110
1987	31,449,430	7,301,000	20,046,700	11,402,730	4,952,208	1,800,000	12,745,700
1988	32,926,880	7,572,000	20,625,370	12,301,520	5,103,665	1,947,000	13,053,370
1989	33,637,100	8,118,000	21,047,470	12,589,630	5,045,082	2,084,000	12,929,470
1990	35,358,000	8,667,000	21,751,710	13,606,290	5,160,574	2,356,000	13,084,710
1991	36,981,800	9,194,000	21,941,240	15,040,570	5,289,139	2,628,000	12,747,240
1992	38,621,040	9,801,000	22,056,490	16,564,560	5,541,071	2,872,000	12,255,490
1993	40,755,080	10,219,000	22,214,310	18,540,770	5,647,207	3,143,000	11,995,310
1994	43,231,620	10,965,000	22,964,070	20,267,560	5,946,080	3,411,000	11,999,070
1995	45,827,720	11,482,000	23,472,020	22,355,700	6,088,102	3,655,000	11,990,020
1996	47,480,220	12,072,000	24,170,120	23,310,100	6,335,834	4,052,000	12,098,120
1997	50,369,280	12,497,000	24,572,940	25,796,330	6,306,571	4,461,000	12,075,940
1998	51,230,020	12,724,000	25,029,930	26,200,090	6,460,470	4,490,000	12,305,930

Table D3 (continued) Turkey Meat Production

Year	World	USA	Developed	Developing	EC(15)	France	DEV-US
1980	2,054,236	1,075,000	1,955,668	98,569	662,927	203,000	880,668
1981	2,155,796	1,150,000	2,047,637	108,159	677,916	218,000	897,637
1982	2,183,527	1,121,300	2,067,646	115,881	726,914	236,000	946,346
1983	2,308,995	1,174,800	2,183,083	125,912	774,020	244,000	1,008,283
1984	2,328,991	1,179,800	2,185,704	143,287	771,597	246,000	1,005,904
1985	2,446,693	1,277,800	2,295,844	150,849	780,480	253,000	1,018,044
1986	2,691,386	1,431,000	2,537,683	153,703	865,351	293,300	1,106,683
1987	3,023,559	1,679,000	2,864,271	159,288	908,567	307,900	1,185,271
1988	3,164,056	1,759,500	3,009,215	154,840	962,605	332,400	1,249,715
1989	3,388,300	1,876,000	3,229,514	158,786	1,051,989	386,800	1,353,514
1990	3,699,168	2,047,500	3,531,145	168,023	1,159,639	439,000	1,483,645
1991	3,807,690	2,088,000	3,649,258	158,432	1,248,676	491,000	1,561,258
1992	4,027,292	2,167,000	3,852,511	174,782	1,363,574	534,100	1,685,511
1993	4,070,268	2,176,000	3,888,343	181,925	1,400,125	532,000	1,712,343
1994	4,205,386	2,239,000	4,019,078	186,308	1,456,057	568,200	1,780,078
1995	4,449,242	2,299,000	4,248,499	200,743	1,578,338	660,000	1,949,499
1996	4,626,438	2,450,000	4,425,642	200,796	1,603,205	650,000	1,975,642
1997	4,775,646	2,455,000	4,563,482	212,163	1,733,538	708,000	2,108,482
1998	4,713,996	2,346,000	4,495,364	218,631	1,765,710	725,000	2,149,364

Source: FAO Electronic Data Base

Table D4. U.S. Broiler and Turkey Exports

	1,000 Pounds	
Year	Broilers	Turkey
1960	93,015	24,145
1961	149,313	27,862
1962	172,577	36,851
1963	112,273	30,888
1964	110,666	43,232
1965	87,912	58,499
1966	90,998	46,950
1967	79,518	48,883
1968	86,026	41,272
1969	83,949	36,597
1970	93,707	34,973
1971	100,543	23,030
1972	94,120	36,389
1973	93,798	49,959
1974	115,342	39,593
1975	137,731	47,307
1976	287,408	65,170
1977	313,287	53,873
1978	331,137	51,067
1979	402,002	50,010
1980	567,050	75,066
1981	719,144	62,984
1982	501,009	51,025
1983	431,755	47,322
1984	406,766	26,544
1985	416,874	27,211
1986	524232	26,637
1987	683,471	33,096
1988	704,210	50,902
1989	741,361	40,580
1990	1,033,316	53,939
1991	1,173,392	122,041
1992	1,371,890	201,829
1993	1,836,350	243,703
1994	2,651,102	280,423
1995	3,623,354	348,012
1996	4,420,000	437,795
1997	4,464,207	603,427
1998	4,672,836	434,767

Notes

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West Virginia University

College of Agriculture, Forestry and Consumer Sciences

WV Agricultural and Forestry Experiment Station
PO Box 6108
Morgantown, WV 26506-6108